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# **The Nature of Science in Science Education**

**A case study of the development of the nature  
of science in the national curriculum for  
science 1988 – 2010**

**Submitted in fulfilment of the requirements for the  
degree of Doctor of Philosophy  
at the University of Sussex**

**James David Williams  
BSc MEd FLS FRSB CSciTeach**

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**UNIVERSITY OF SUSSEX**

**James David Williams**

**Doctor of Philosophy**

**The Nature of Science in Science Education:  
A case study of the development of the nature of science in the National  
Curriculum for science 1988 - 2010**

**SUMMARY**

This thesis is a case study of the educational, political and organisational influences on the development and introduction of the science national curriculum in England and Wales, latterly England only, from 1988 – 2010, with particular emphasis on the inclusion of the Nature of Science (NoS).

The NoS is an important philosophical construct that describes the epistemology of science, that is, science as a way of 'knowing'. Previous research on the NoS has concentrated on teachers' and children's understanding of the concept. There is little published work on how the concept is included and represented in the curriculum and how curriculum reform has affected the development and status of the NoS.

I argue that a lack of understanding of the nature of science as well as a confusion over the so-called 'scientific method' has led to a lack of coherence in the science curriculum and, further, that simply teaching children 'in' science does not develop the necessary skills or knowledge to be 'scientifically literate'.

The research was carried out within a post positivist, critical realist paradigm. Methods used include document analysis, a curriculum analysis utilising Posner's framework and semi-structured interviews.

The case study covers three distinct areas; firstly, there is a consideration of the development of science in the school curriculum over time. It includes recognition and discussion of various education acts, Government reports and other expert science education reports, including notable science curriculum developments leading up to the introduction of the science national curriculum for Science. Secondly, there is an examination of the political influences on the introduction of the national curriculum, followed by an analysis of the various draft and implemented versions of the science national curriculum during the stated period. Finally, there is an analysis of the experiences of a small sample of science teachers focussing on their experiences of science education, their understanding of the NoS, the scientific method and aspects of scientific language.

The case study shows the influence of Government policy over the curriculum. It reveals how a reductionist approach to curriculum review almost eliminated the essence of the subject (the NoS) in favour of a utilitarian model based on knowledge and skills only, which prized science literacy over scientific literacy.

The key findings from this research are:

1. A lack of a properly formed and informed view of the Nature of Science in the science curriculum has the potential to undermine the development of high levels of scientific literacy.

2. The process skills of science, that is how to conduct experiments and investigations, are likely to be seen as a proxy for the NoS if a coherent position on the NoS is not presented as necessary to underpin science teaching.
3. The creation of a curriculum by consensus and in prescriptive detail was ineffective and led to several revisions, which further complicated its implementation nationally.
4. There is a problem with the lack of agreement and consistent definitions of key terms and the concept of 'the scientific method', as revealed in the interview evidence, which undermines the teaching and understanding of the nature of science.

The findings from this case study show that a lack of understanding of the NoS potentially undermines the delivery of high levels of scientific literacy. It can also lead to a belief that 'the sciences' have a high degree of commonality in how they operate as disciplines and in the reasoning skills applied within the different disciplines to scientific problems. This leads to a lack of coherence in the curriculum as the sciences have distinct features and processes that define how they operate in real life. As a contribution to knowledge, I argue that the teaching of, understanding and delivery of a coherent nature of science should underpin any science curriculum constructed to ensure a greater degree of curriculum coherence and appreciation of the similarities and differences between the scientific disciplines. The nature of science provides an epistemological basis for all the sciences and underpins the scientific methods and language related to ideas and evidence. Furthermore, there should be more attention paid to the language of science and, to separate out the specific language used by science, the prefix of 'scientific' should be used preceding key terms such as theory, law, hypothesis, principle etc. This has implications for initial teacher education and training in ensuring that science graduates appreciate the NoS and understand the reasoning and methods used by different sciences to come to answers about scientific questions.

## **Dedication**

**The entire thesis is dedicated to my wife, Joan.  
Without her support and encouragement, I would never have completed this  
mountainous task**

## Acknowledgements

Attempting this PhD was like '*Climbing Mount Improbable*', (taken from the Richard Dawkins book of the same name) would I ever reach the summit and complete it successfully?

This thesis stems from an interest in science. The front wall of my childhood home, which contained fossils, initiated my interest in science, especially geology and evolutionary palaeontology. My interest in the history of science and evolution began by wanting to know more about Alfred Russel Wallace, especially why he deserved a wall-plaque on a building in my home town – this was encouraged by my late father, Ralph.

My late sister, Christine, always said of me – '*all brains and no common sense*'. If I gain this degree, her words will come true. My mother, Betty, never tired of asking '*how is the PhD going?*' at last I can say, '*it's finished mum.*'

My wife Joan, also my best friend, is a work colleague and is my greatest critic. If she reads my work, she will let me know, in no uncertain terms, what's good, what's bad and she will correct my errant apostrophes and poor grammar – though any errors that remain are down to me, not her.

I would like to thank all my grandchildren for lending me their names as interviewee pseudonyms. Isobel, Thomas, Sophie and Ellis. Lola and Harrison did not quite make it into the thesis due to issues of interviewee consent but were on standby.

Finally, thank you to all my supervisors, Professor Jo Boaler, Dr Jim Endersby, Professor Judy Sebba, Dr Ricardo Sabbates, Dr Barbara Crossaud, Dr Naureen Durani and Professor Kwame Akeyampong and my work colleagues. Perhaps I can stop telling my well-worn (and by now despised) 'joke' when they ask how my thesis is going:

"I'm in the Morecambe and Wise phase" I'd say, "you know, when André Previn accuses Eric of playing the wrong tune? Well, just like Eric I have all the right words sunshine, but not necessarily in the right order".

I just hope that what is written here is, at last, all the right words and all in the right order.

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## Abbreviations

<b>AT</b>	Attainment Target
<b>BEd</b>	Bachelor of Education
<b>BoE</b>	Board of Education
<b>BTEC</b>	Business and Technology Education Council
<b>CLISP</b>	Children's Learning in Science Project
<b>CSE</b>	Certificate in Secondary Education
<b>DCSF</b>	Department for Children Schools and Families
<b>DES</b>	Department for Education and Science
<b>DfEE</b>	Department for Education and Employment
<b>DfES</b>	Department for Education and Skills
<b>DNA</b>	Deoxyribonucleic Acid
<b>DSA</b>	Department of Science and Art
<b>ERA</b>	Education Reform Act
<b>ERIC</b>	Education Resources Information Center
<b>GCSE</b>	General Certificate in Secondary Education
<b>GCE</b>	General Certificate in Education
<b>HORSA</b>	Hutting Operation for the Raising of the School Leaving Age
<b>HPS</b>	History and Philosophy of Science
<b>HSW</b>	How Science Works
<b>iGCSE</b>	International General Certificate in Secondary Education
<b>ITT</b>	Initial Teacher Training
<b>JSTOR</b>	Journal Store: digital library of academic journals, books, and primary sources
<b>KS</b>	Key Stage
<b>LA</b>	Local Authority
<b>LEA</b>	Local Education Authority
<b>LHC</b>	Large Hadron Collider
<b>LMS</b>	Local Management of Schools

## Abbreviations (cont.)

<b>MPhys</b>	Master of Physics
<b>MoE</b>	Ministry of Education
<b>MSC</b>	Manpower Services Commission
<b>NAT</b>	New Attainment Target
<b>NC</b>	National Curriculum
<b>NCC</b>	National Curriculum Council
<b>NC NoS</b>	National Curriculum Nature of Science
<b>NOMA</b>	Non-Overlapping Magisteria
<b>NoS</b>	Nature of Science
<b>NoSI</b>	Nature of Scientific Inquiry
<b>OED</b>	Oxford English Dictionary
<b>OFSTED</b>	Office for Standards in Education
<b>OFQUAL</b>	Office of Qualifications and Examinations Regulation
<b>PCK</b>	Pedagogic Content Knowledge
<b>PoS</b>	Programme of Study
<b>QCA</b>	Qualifications and Curriculum Authority
<b>ROSLA</b>	Raising of the School Leaving Age
<b>SAT</b>	Standard Assessment Task
<b>SATIS</b>	Science and Technology in Society
<b>SCAA</b>	School Curriculum and Assessment Authority
<b>SCISP</b>	Schools Council Integrated Science Project
<b>SoA</b>	Statements of Attainment
<b>SSCR</b>	Secondary Science Curriculum Review
<b>SWG</b>	Science Working Group
<b>TVEI</b>	Technical and Vocational Education Initiative
<b>UIFSM</b>	Universal Infant Free School Meals
<b>YOP</b>	Youth Opportunities Programme
<b>YTS</b>	Youth Training Programme

## Notes on Terminology

**Children** is used rather than ‘pupils’ or ‘students’. Internationally, the term ‘pupil’ is used inconsistently, though the concept of a child i.e. a young person under the age of 16 is universal. This thesis considered the science education of children generally between the ages of 11 and 13. There is reference within the thesis to ‘students’ as in students in initial teacher education, so to avoid any confusion ‘children’ was chosen as the preferred label, over ‘pupils’ or ‘students’.

**Initial Teacher Training** is used to denote the period of pre-service teacher training. I would prefer the term Initial Teacher Education (ITE) as I believe that professionals are educated rather than simply ‘trained’, but the use of ITE is not consistent in the UK. The Government organisation in charge of the regulation of teacher qualifications preferring ‘training’ over ‘education’ hence my choice of this term.

**Scientific Inquiry:** ‘Inquiry’ and ‘Enquiry’ have the same meaning according to the Oxford English Dictionary (OED). Inquiry is more often used in the US, whereas enquiry is ‘British’. I have chosen to use ‘inquiry’ over ‘enquiry’ for etymological reasons. The word ‘inquire’ and ‘inquiry’ date back to the 15<sup>th</sup> Century where it was defined as *"a judicial examination of facts to determine truth"*. Enquiry, on the other hand, is most commonly used, according to the OED, in the sense of simply ‘asking a question’. For this reason, I chose to use ‘Inquiry’ as a more rigorous term suited to examining the ‘facts’ or observations made in scientific experiments and investigations. Where official documents or quotations use the term ‘Scientific Enquiry’, I preserved the original spelling for accuracy.

## Chapter 1

### Introduction and General Context

This is a case study considering what influenced the origin, development and evolution of the science national curriculum (SNC) in England and Wales (latterly England). The period being studied runs from 1988, the initiation of the SNC, to 2010 at which point a change in Government (from a single party New Labour Government, to a coalition Conservative/Liberal Democrat Government) resulted in a major shift of policy with respect to the whole national curriculum (NC). The case study examines and analyses the political, educational and organisational influences on the NC and the SNC by examining how one component, the nature of science (NoS) evolved and developed.

There are those who look at science as being part of a 'rounded' education that aims to produce 'scientifically literate' children to ensure a 'general public understanding of science' (Millar and Osborne, 1998; Nelson, 1998; Jenkins, 1999; Millar, 2001; Roberts and Bybee, 2014). Others see a science education as necessary for the supply of scientists and technologists who will contribute to the economic well-being of a nation (Anon, 1998; Roy, 1999; Drori, 2000; Donovan *et al.*, 2014). Few, if any, whole school curriculum producers see the inclusion of science as a core or main aspect of the curriculum as too dominant and unwarranted (Jenkins, 1998). Terms such as 'scientific literacy' or 'public understanding of science' are used to justify science in the school curriculum. There is also a tacit assumption that teaching science will achieve this (Bybee, 1997; DeBoer, 2000; Millar, 2007; Webb, 2010). The NoS is considered as a key component of scientific literacy (Holbrook and Rannikmae, 2007; Allchin, 2014; Van Dijk, 2014; Reiners *et al.*, 2017). As this is the case, the NoS should have a central role within any science curriculum.

This chapter introduces the research and explains the rationale for the case study. I will then explain my motivation for conducting the research and explain why I took a case study approach. My research questions are set out in Chapter 4, alongside a description of my theoretical approach. My general aims for carrying out the research are detailed towards the end of this chapter.

### 1.1 Defining the nature of science in the curriculum

In articulating the NoS we necessarily go beyond a simple explanation of what science 'is' and ask much more deeply philosophical questions, such as 'what makes science, science?' or, 'can we differentiate between the scientific study of things and a non-scientific approach?'

The NoS is important (as will be briefly evidenced in section 1.2 below), but in the case of the SNC there is no detailed description, justification or reasoning as to why this is the case and how the NoS contributes to the curriculum or scientific literacy overall, just that it does. There is also an anomaly that became apparent from my experience of teaching children and science graduates training to be science teachers, that some teachers see the experimental skills of science or 'scientific inquiry' as being synonymous with, or a proxy for, the NoS.

Lederman and Abell (2007, p.833) attempt a general definition of the NoS as '*the epistemology of science*' that is, science as a way of knowing along with the values and beliefs inherent in scientific knowledge and its development. They provide a summary of the characteristics of the NoS for science education purposes. Their view is that this is what students should glean from teaching that covers the NoS (Lederman and Abell, 2007, p.833):

- There is a distinction between observation and inference.
- That there is a distinction between laws and theories.
- That science involves creativity and imagination.
- That scientific knowledge is subjective and/or theory laden.
- That science as a human enterprise is practised in the context of a larger culture.
- That scientific knowledge is never absolute or certain.

To ensure that there was a manageable and consistent view of the NoS applied in this case study, the six characteristics above underpin analyses of the NoS within this case study.

### 1.2 Science and the nature of science in the curriculum

There are many educational justifications for the inclusion of the NoS within a science education curriculum for schools (McComas *et al.*, 1998; McComas and Olson, 2002; McComas, 2002; McComas *et al.*, 2002; Osborne *et al.*, 2003; Monk and Osborne, 2006). Justifications include: enhancing children's understanding of science; increasing their interest in science; to show that science involves creativity and that science is a human endeavour. The NoS helps children understand what scientific

knowledge is relevant, how to recognise the reliability of the information with which they are presented, how that information was generated and the limits of scientific knowledge. Such justifications are an example of educational influence.

What influences the curriculum and its content is not determined solely by teachers or science education experts. There are others, e.g. employers, universities and politicians in Government who may wish to influence what is studied or even how something is studied within schools. Whether their influence is justified, or ends in change, is a complex matter. For example, one political justification for a knowledge-based and rigorous science curriculum in schools is a politically perceived need to address our global position in international rankings of educational achievement, such as PISA (Programme for International Student Assessment). In 2015, PISA focussed on science. It placed the UK in 15<sup>th</sup> place (a rise of 6 places from 2012), though the UK's point score dropped from 514 to 509 (OECD, 2016). 'Something must be done' is the political mantra of change. Change will focus on those things that will affect the outcome, rather than what is necessary for a 'rounded' education in science. Knowing the facts of science and understanding key concepts in science may be enough to improve our international standing without teaching children aspects of the history, philosophy of science or the epistemological basis of science, so proposed changes may ignore the NoS, leading to change that focuses on science knowledge.

Politicians (from across the political spectrum) will use international comparisons to invoke curriculum change. How specific the changes are and what changes are made will depend on the ideology, background and power the person/group has promoting the need for change. An example of such change, proposed by the political establishment, is the major reform of the curriculum and examination system that took place after the 2010 General Election in the UK. Major curriculum reform was proposed and enacted by Michael Gove (b.1967-) when he took office as Secretary of State for Education. This was driven by a desire to return to traditional subjects and a knowledge-based curriculum. In a speech to the Royal Society of Arts in June 2009 Gove signalled his intentions, should his party come to power, by saying '*We will completely overhaul the curriculum - to ensure that the acquisition of knowledge within rigorous subject disciplines is properly valued and cherished*' (Gove, 2009). Change was predicated on a vision of the curriculum from the past, rather than a specific identified need.

### 1.3 Rationale for the study

The NC became statutory in all state schools in England and Wales from 1989 (DES, 1988a;1989). It was seen as a means of ensuring a commonality of experiences in various subjects for children. While the subject content within the NC was ‘common’, and the overall structure of each subject curriculum was common, how the NC was enacted was down to individual schools and teachers.

As a teacher of sciences in state schools for 12 years, which included the early period of curriculum and examination reform this thesis examines (1988 -1997), I was aware of several issues that surrounded the introduction and evolution of the SNC and the introduction of the NoS as a discrete concept within science teaching and learning. Teachers of science I was working with, communicating with and who attended science education conferences I attended, would often confess not to understand what the NoS component of the proposed new curriculum was supposed to do, what it meant in practice and how to incorporate it into their teaching.

The situation persists to this day (Bayir *et al.*, 2014; Leden *et al.*, 2015). That is, there is still a lack of understanding and explicit teaching about the NoS, which in my view contributes to ongoing issues of coherence in the science curriculum. Education reforms, including the setting up of the NC and reforms enacted since 2010, following the election of a coalition Government, have often focused on a return to traditional teaching and traditional subjects, with the learning of facts and knowledge recall as the core of good teaching and learning. Ball (1995, p.87) describes this type of reform as:

reinventing the educational past, what is sometimes called ‘cultural restorationism’ – a curriculum based on traditional subjects, canonical knowledge and a celebration of all things English; a curriculum of facts, lists and eternal certainties.

Curriculum reform has dominated the operation of schools and the content of subjects for the past 30 years.

As I researched aspects of the NoS, it became clear that while a lot had been written about teachers’ and children’s understanding of the NoS, less had been said or researched on how the NoS is included in any curriculum, why its inclusion is important and whether explicit teaching on integration of the NoS into everyday science teaching is best. Taber (2008; 2014; 2017), however, has published some very useful and insightful research related to this aspect of the science curriculum, which will be reviewed in Chapter 3.

#### **1.4 Personal motivations for conducting this case study**

In my time as a science teacher and Head of Science, it became apparent to me that the sciences we taught lacked coherence. How we taught physics, as a deductive process where experimentation ‘confirmed’ theory, was very different to the inductive, observational, comparative science of biology. The language of science was also an issue. The meaning of ‘theory’ to a physics teacher I worked with differed from the meaning ascribed by the biology teacher; the former saw theories as something to be ‘proven’ mathematically and the latter as confirmed hypotheses. Other teachers had issues with the relationship between theories and laws. Although theories were considered to be ‘correct’, they could not be ‘true’ otherwise they would be laws (one common misconception that existed with my teaching colleagues). This was an example, for me, of an incoherent view of the NoS. It showed a misunderstanding of the status and meaning of law and theory in science. It also highlighted a problem with how we define key terms, which had the potential to confuse children. This lack of coherence had a wider implication, in that it exposed differences between the science disciplines.

During my time as a science teacher, changes in the curriculum were clearly influenced by different groups of people, e.g. politicians, Her Majesty’s Inspectorate (HMI), local and national science advisers and teachers. Content was removed from the curriculum, or moved, and the structure of the curriculum changed substantially in the first few years of its existence. This added to my sense of a lack of overall coherence.

How the curriculum was organised in schools also affected how it was enacted. The sciences could, for example, be taught separately by specialists or separately by generalists. It may be taught as general science in lower secondary schools and specialist subjects for the later public examination years or it could be general science all through. The time devoted to science across secondary schools also varied. Several broader issues, identified by employers, teachers and Government also potentially affected curriculum coherence. Employers, for example, were focused on skills training and numeracy/literacy. Government wanted a greater uptake of science post 16 and at university to secure our future as a leading scientific and technological world power. Teachers wanted children to be engaged and take up science and to become scientifically literate. In some schools getting children to choose science post 16 was related to keeping alive the sixth form and overall school numbers.



The 'dumbing down' narrative of public examination and NC test results, which was characterised by those who considered the ever rising numbers of higher grades from 1988 to 2010 as proof of this narrative, was a political football. Science was used for political ends, along with other core subjects, to impose a wholesale change and reform of the curriculum (Lightfoot, 2010). Those in political power saw increasing results as affirmation of their education policies, those in opposition saw increasing results as a failure to tackle poor standards by making tests and examinations easier with teachers 'teaching to the test'.

Having left teaching in state education in 1997 I began a new phase in my career, training science teachers. As a geology graduate, I had a reasonable grasp of all scientific disciplines having studied geophysics, geochemistry, palaeontology and planetary geology as part of my degree. I had also taught all the sciences to GCSE level and biology to A level. It was apparent to me, while working as a science educator in initial teacher training (ITT), that many science graduates did not have a breadth of understanding of the main three science disciplines. In extreme cases, I encountered physics graduates who had little to no knowledge of biology and chemistry beyond GCSE and biology (or biology related) graduates who had shunned physics after GCSE, in addition to this lack of subject knowledge across the disciplines, few had knowledge and understanding of the NoS. To be successful within a science did not require an explicit understanding of the NoS.

During my time in ITT, Government tended to focus on the supply of science teachers, particularly specialist teachers for separate sciences. The reality in state schools was that new science teachers, even if they were hired because of their specialism, were required to teach all science disciplines to age 13 and often two or more to age 16. Only in post-16 education were teachers 'specialist teachers' of a single science. The Government was also aware of an issue related to subject knowledge for teachers and in 1997 introduced a national curriculum for ITT (Emery, 1998). The 'issue' was the supply of subject specialists, in particular for the physical sciences such as physics and to a lesser extent chemistry linked to the need for all science teachers to teach all sciences to at least 14, often teaching all sciences to 16.

It was apparent after surveying science graduates entering ITT at a University on the South Coast of England, to ascertain their level of subject knowledge across the sciences, that many did not have any specific knowledge of or much understanding about the NoS. They also had mixed ideas about 'the scientific method' (TSM) and often viewed this, combined with scientific inquiry (SI), as a proxy for the NoS.

Research carried out on one aspect of the NoS, scientific language, also uncovered issues relating to how key terminology (theory, law, principle etc.) was defined by graduates of different sciences (Williams, 2013). This research links to this PhD study in that understanding the definitions of key terms is a fundamental aspect of understanding the NoS. It was this research in part that stimulated this case study.

This case study examines the political, educational and organisational influences on the production of a national curriculum for all state schools, but within this it reviews how the NoS was introduced into the science national curriculum (SNC) using curriculum and document analysis. This illustrates how its prominence and status changed over time with respect to the political, educational and organisational influences. Supplementing the curriculum and document analysis, interviews with four current sciences teachers, taught using the SNC as children, record aspects of their formal and informal science education experiences as well as their understanding of aspects of the NoS and TSM. From this case study, it will be possible to come to some conclusions about the nature of the successes and failures apparent in trying to incorporate the NoS in a SNC.

### **1.5 Defining 'curriculum'**

The term 'curriculum' has a fluidity in meaning. The curriculum could encompass everything that a child is exposed to in an educational setting across the whole time he/she is in school. Likewise, curriculum may mean a collection of subjects studied e.g. a humanities curriculum or, in this instance, a collection of scientific disciplines – packaged as discrete yet interconnected subjects called 'science'. This is a definition that Goodson (2005, p.27) provides as a general 'working' definition.

How society, teachers, education managers and politicians visualise a curriculum is subject to variation. As UNESCO (2017) state online, there are many different ways of envisaging a curriculum:

What societies envisage as important teaching and learning constitutes the "intended" curriculum. Since it is usually presented in official documents, it may be also called the "written" and/or "official" curriculum. However, at classroom level this intended curriculum may be altered through a range of complex classroom interactions, and what is actually delivered can be considered the "implemented" curriculum. What learners really learn (i.e. what can be assessed and can be demonstrated as learning outcomes/learner competencies) constitutes the "achieved" or "learned" curriculum.

This thesis focuses on the written or official curriculum rather than the implemented curriculum. A sense of the achieved or learned curriculum is examined in a limited way through the analysis of the interviews with the four science teachers, all of whom attended schools that taught science during the era of the SNC versions examined in this case study. Rather than looking at the whole school curriculum, i.e. everything a child was exposed to within a school, this thesis concentrates on the curriculum for science, especially that intended for teaching at Key Stages three and four (between the ages of 11-16) in schools in England and Wales (latterly England only).

The curriculum analysed for the purposes of this thesis is the combined content from five separate science disciplines (biology, chemistry, physics, astronomy and geology) combined into one document called 'science'.

Posner (2004), whose framework for curriculum analysis is used to analyse the various curriculum documents in this case study, addresses the question of defining the curriculum by stating that it should be seen as a matter of 'means' and 'ends'. For Posner a 'means' curriculum would entail teaching plans whereas an 'ends' curriculum would be a set of intended learning objectives or outcomes. A third view put forward by Posner is that a curriculum should be seen as the actual (not the intended) outcomes achieved by children. In Posner's sense, the curriculum being examined in this case study is an 'ends' curriculum in that it consists of a set of intended learning objectives or outcomes.

### **1.6 Defining the 'case' in the thesis**

Case studies are defined by Stake (1995, p.2) as '*...specific, complex, functioning things...a "bounded system"*'. Yin (2013, p.16) defines a case as a '*contemporary phenomenon*'. Clearly, in this instance, while there is a curriculum that is contemporary, the case itself covers a different, but precise period, from 1988 – 2010.

The NC proper began in 1988, with the passing of the 1988 Education Reform Act (ERA). In 2010 New Labour, which had been in power and in control of the NC since 1997, lost a General Election to a new coalition Government made up of Conservatives and Liberal Democrats. By studying this specific period, over which two ideologically opposed political parties were in power, political influences can be identified and analysed through the various versions of the SNC. The decision to end the analyses in 2010 marks the point at which new era of radical change and reform was introduced. It also marks the point at which competing political ideological approaches to education (Liberal Democrat and Conservative) would influence Government policy, rather than it being one dominant political ideology. Those

reforms are ongoing and affect not just the curriculum but the structure of the GCSE examinations as well. As this is a case study, the specific time period provides a natural boundary within which the GCSE examinations remained unchanged and constant. The overall content remained relatively stable, whereas post 2010 the intent was to make the examinations more rigorous through the inclusion of more difficult content.

There are some key characteristics of case studies that make it the most appropriate methodological approach for this research. As Stark and Torrance (2004, p.33) say, '*(A) case study... is particular, descriptive, inductive and particularly heuristic.*' It is analytic and can be seen as a methodological approach in its own right (O'leary, 2014). Cohen *et al* (2013) describe the hallmarks of a good case study, which includes rich and vivid descriptions of events pertinent to the case, chronological narratives, a blend of description and analysis and it records specific events. All these characteristics are present within this thesis. In terms of its basic design, this case study is a retrospective one (Flick, 2009), where the process of curriculum design and development has been reconstructed from the available documentation, reports, policies and statutes (see appendix A for a full list).

The 'case' being studied is therefore a case of how political, educational and organisational influences shaped the NC and the impact these influences had on the science curriculum as presented in school science curriculum documents in England and Wales. The case study explores the key problems that arose when the original curriculum (and its revisions) were implemented.

### **1.7 An overview of the research strategy**

The methods chosen for this case study included a textual analysis of the SNC documents, biographical/autobiographical writing, printed media reports and semi-structured interviews with science teachers. The methods chosen enabled themes and sub-themes to be uncovered which guided my conclusions by providing evidence to support my interpretations. The methods chosen also fulfilled the basic characteristics of a good case study as described by Cohen *et al.* (2013), that is, it should provide rich descriptions and chronological narratives with a blend of description and analysis.

#### **1.7.1 Curriculum analysis**

The main analysis utilised Posner's (2004) framework for curriculum analysis, which is divided into four sets. Set one asks: "How is the curriculum documented?" and "What situation(s) resulted in the development of the curriculum?" Set two asks "What

are the purposes and content of the curriculum?” and “How is the curriculum organised?” Set three is not used for this case study as it is an analysis of the curriculum in use. As this is a retrospective analysis, the various versions of the curriculum cannot be observed or analysed ‘in use’. Some indication of set three, however, did emerge from the recollections and experiences of the interviewees. Set four is a critique of the curriculum, which will be set out in Chapter 10 as part of the findings and discussion.

### **1.7.2 Document analysis**

A major element of this research and of the case study is document analysis. This is a process of gathering relevant documentation e.g. various education acts, education reports (from bodies such as Her Majesty’s Inspectors, government education department commissioned reports and education quangos) and curriculum documents in a variety of outputs digital, online, hard copy etc. The documents range in age from the Taunton Commission report (Taunton, 1868) on the state of education in England and Wales, to the various SNC documents. A full list of the various documents analysed is documented in appendices A1, A2 and A3. Each of the documents was then analysed using a document analysis framework (appendix B) to discover meaning and, possibly, the intent behind the documents.

### **1.7.3 Semi-structured interviews**

In addition to document analysis, the case study also utilised semi-structured interviews with four science teachers who teach one or more of the three main science disciplines offered in schools (biology, chemistry and physics). The purpose of the interviews was to gather evidence of their experiences of formal science teaching experienced under the various versions of the science curriculum from 1988. The interviews include some rich and vivid descriptions of events pertinent to the case (memories of school science), as well as analysis of their understanding of some key aspects of science related to the NoS and TSM. In particular the interviews were carried out to ascertain how a small sample of science teachers view the different science disciplines and their vision of the NoS, two aspects of the research questions that drive this case study (see section 4.1, the research questions). The intent here was not to ascertain what other major studies had already achieved with respect to teachers’ understanding of the nature of science (e.g. Brickhouse, 1990; Lederman, 1999; Abd-El-Khalick and Lederman, 2000; Miller *et al.*, 2010; Bilican *et al.*, 2012; Bektas *et al.*, 2013). It was to focus on any tacit or explicit knowledge they may have that would enable or restrict them from delivering the NoS within the curriculum.

### **1.8 Research aims**

Following the background above which explains the origin of my interest in and initial thoughts on the NoS and the science curriculum the aim of this research is to understand the influences and tensions that underpin the development of a major education initiative. The broad aims were:

- 1) to understand how the SNC and the lead up to it was influenced by politics/politicians, educators and teachers;
- 2) to examine how the NoS was incorporated the SNC;
- 3) to ascertain how the NoS changed and developed over time and uncover any problems associated with coherence across the sciences.

### **1.9 Central themes of the thesis**

A broad review of literature, the analyses of the various documents/reports etc., revealed three key themes that run through the thesis:

- Political – the influence of politicians or party-political ideology on the form and content of the science national curriculum.
- Educational – the influence of key educationists or the educational establishment (prominent schools, universities etc.) on the content and structure of the science education curriculum.
- Organisational – the influence and practicalities of the teaching of science in schools in England and Wales during the period under review.

### **1.10 The structure of the thesis**

Chapter 2 provides a rich chronological narrative of the place of science in the school curriculum. Understanding how science developed in the school curriculum from the 19<sup>th</sup> Century through to 1988 places the first SNC in a historical context. The various influences, as described above, on science in the curriculum across this period are also relevant to understanding how and why the modern science curriculum was constructed the way it was.

Chapter 3 reviews the literature pertinent to the case study. It looks at what we know about the NoS, how it is taught and teachers' understanding of the NoS. The myth of 'the scientific method' is reviewed as well as its place within the NoS. A section on scientific literacy, what this means and how the NoS contributes to this is included as well as a brief review of what is meant by 'a curriculum'.

Chapter 4 details the research questions the case study sets out to answer. It also explains how I arrived at my theoretical position, after which I set out my ontological, epistemological and axiological stances. Next, the methodological approach and the methods used are set out and discussed. Reliability, validity and the generalizability are discussed along with any strengths, weaknesses and limitations of the research.

The final section of the chapter looks at ethical considerations and discusses one issue that did arise concerning withdrawal of consent.

Chapter 5 examines and analyses the educational and political origins of the NC generally and the SNC specifically. The chapter is split into two parts. Part 1 analyses the educational origins looking various reports and documents reviewing the state of education and science education in England and Wales.

Part 2 analyses the political origins of the National Curriculum by analysing the biographies/autobiographies of the key politicians involved in its development. Political, educational and organisational influences are analysed. These two sections fulfil set one of Posner's (2004) framework for curriculum analysis.

Chapter 6 utilises Posner's curriculum framework (set two) to analyse the curriculum proper. In this chapter the first draft consultation document (DES, 1988b) is the focus and, within that, how the NoS is defined and set out is analysed and compared to the view of the NoS set out earlier (Lederman and Abell, 2007).

Chapter 7 analyses curriculum reform from 1989-1999. This period covers the first enacted SNC (DES, 1989) which became statutory in 1989 and the various draft and enacted revisions of that curriculum.

Chapter 8 analyses the various revisions of the science National Curriculum from 1999 to 2010. The analysis once more focuses on the NoS element of the curriculum.

Chapter 9 analyses the experiences of four science teachers using Thematic Content Analysis (TCA) (Braun and Clarke, 2006). In one respect, they provide instances of the enacted taught curriculum from their memories of school science at both primary and secondary level. The analysis also considers their understanding of TSM and the language of science associated with the NoS.

Chapter 10 sets out the findings from the case study and is followed by a discussion of these with a brief outline of the contributions to knowledge this thesis makes as well as recommendations for curriculum development offering some potential solutions to issues and problems that emerged from the various analyses and opportunities for further research.

## **Chapter 2**

### **Historical Context**

From the start of state involvement with education, politicians in England particularly have exerted an influence on key aspects of educational provision, especially the organisation, structure and types of schools. This chapter provides background for this case study in the form of a rich chronological narrative of the political, educational and organisational influences on the introduction of science as a core curriculum subject.

The history of the sciences within the curriculum, the state involvement in education and the influences of scientists, such as T.H. Huxley (1825–1895) and H.E. Armstrong (1848–1937) are pertinent to how we view the curriculum today and how the curriculum has been shaped. By understanding some of the past political, educational and organisational influences on science education, light can be shed on similar influences at the time of the introduction of the NC. Having looked at the origins of school-based science education, I will consider how science education became the more organised disciplines we see delivered today and how this impacts on the overall curriculum.

#### **2.1 The origin of the modern ‘sciences’**

A full history of the origins of scientific thinking and the progress of science from ancient times through to the scientific revolution and to the present day is beyond the remit and scope of this case study. Such historical treatments are well covered in a range of academic (Nye, 2002; Porter, 2003; Porter and Ross, 2003; Park and Daston, 2006; Bowler and Pickstone, 2009; Lindberg and Shank, 2013; Jones and Taub, 2019) and popular books (Gribbin, 2002; Bryson, 2004; Wootton, 2016).

To contextualise this research, I will chart briefly some aspects of the history of science, followed by the introduction of science into education from the early 19<sup>th</sup> century onwards.

#### **2.2 Nineteenth century science**

Until the early 19<sup>th</sup> Century, the study of what we now call science was commonly called natural philosophy. William Whewell (1794–1866) proposed the term ‘scientist’ to describe those who studied the natural world. He formally put forward the name ‘scientist’, alongside ‘physicist’ in 1840:



As we cannot use physician for a cultivator of Physics, I have called him (sic) a physicist. We need very much a name to describe a cultivator of science in general. I should incline to call him (sic) a Scientist. Thus we might say, that as an Artist is a Musician, Painter, or Poet, a Scientist is a Mathematician, Physicist, or Naturalist. (Whewell, 1840 p.cxiii, cited in Ross, 1962 p.72)

Whewell initially intended to use the name 'physicist' rather than 'scientist' for the group of people who studied the natural world. He would have preferred to use the name 'physician' for those who studied physics, but as he explains, 'physician' was already taken by another branch of science, medicine. What is interesting is how Whewell describes a 'scientist' – not as a biologist, chemist or physicist, but as a '*Mathematician, Physicist or Naturalist*'. Whewell, thought of mathematics as a branch of science rather than as a separate discipline. Physics was another separate branch. Biology, and the study of the natural world which would include chemistry, makes up the final branch. In its earliest days, the subject of 'science' in schools or in everyday life was not as we conceive it today as biology, chemistry and physics.

### **2.3 The beginnings of school science**

A minority of public and endowed grammar schools led the way in the provision of science teaching and experimental science. Stonyhurst College, a Roman Catholic Independent school in Lancashire, was teaching science in the early part of the 19<sup>th</sup> Century and had its own astronomical observatory, built in 1838 (Jenkins, 1979).

William Sharp (1805–1896) is credited as being one of the early school-based science teachers. He was given the post of 'Reader in Natural Philosophy', at Rugby School, Warwickshire, in 1847. He left in 1850 to devote more time to medical research (Leary, 2013).

The foundation of science as a more widespread subject in schools came with the publication of a report by the British Association for the Advancement of Science (BAAS) in 1867, *Scientific Education in Schools*. The report defined science education as consisting of chemistry, biology, physical and mathematical sciences, and geology. The resultant curriculum, however, marginalized issues and values related to everyday life. It was a knowledge-based curriculum, an attempt to promote a 'pure form' of the sciences and detach it from technology – the application of scientific knowledge to solve problems.

As well as promoting pure science, the BAAS report emphasized the teaching of scientific thinking. One outcome for science education, according to the report, was

to deliver pre-training in science to meet the needs of industry for qualified scientists and technologists, a utilitarian view of science. A second possible outcome was to promote a public understanding of science. The utilitarian view became the driving force for science education in schools (Layton, 1974). Alongside the teaching of scientific 'knowledge', there is experimental science, which would require a laboratory in which experiments could take place.

#### **2.4 Science at Eton: an educational/organisational problem**

It was noted in a House of Lords debate in 1868, by 5<sup>th</sup> Earl Stanhope (1805-1875), that the inclusion of 'new' subjects was causing issues in the organisation of the curriculum in some public schools. Stanhope received from Eton School a report of the teaching of sciences, which stated that:

some branch of physical science is taught compulsorily throughout the fifth form to the top of Division 4. The branches now being taught are physical geography, mechanics, hydrostatics, optics, astronomy. These divisions (4 to 11) comprise about 280 boys. (Hansard, 1868, p.1541)

Stanhope noted that the curriculum was being squeezed. He believed studies of classical Greek literature could be lost or reduced as such studies were 'stationary', in favour of the sciences, which he called 'progressive'. The science being taught at Eton was not in the form of the BAAS definition of science, or the more modern disciplines of science (biology, chemistry and physics), but specific aspects of science such as optics or mechanics etc.

The curriculum at Eton was heavily classical in nature. Mathematics, for example, was only introduced in 1836 (Hansard, 1868, pp.1540-1545). Stanhope was responding to a report from 1864 that looked at standards in public schools. Education was, even at that point, a political issue that merited discussion and debate in both Houses of Parliament. It was noted that neither the government, nor the Lords, had any power whatsoever to change or force the introduction of any subjects within schools, but Stanhope asked whether or not *'measures of a practical character might not be introduced which might facilitate the improvements we desired to see effected in the course of studies'* (Hansard, 1868, p.1539). The desire of politicians to want to exert some form of control over what is taught (not just in state schools, but also the public schools) is deep seated. This is an early example of an attempt to impose a political ideology on a school.

## **2.5 The political influence over 19<sup>th</sup> Century science in schools**

Several reports, education acts and initiatives have influenced the science curriculum in schools. What follows is a summary of these reports and acts. It is helpful to look at how legislation and official reports have regularly informed the course of the curriculum in schools as part of this case study as it establishes the form and extent of political influence over the structure of schools and the curriculum provided by schools. Figures 2.1; 2.2; 2.3 and 2.4 set out some of the major landmark acts of Parliament and reports on education. It is by no means a complete list but serves to set out the political landscape that contributed to curriculum change. Figure 2.1 sets out a timeline of Education Acts from 1902 – 1979. Figure 2.2 has a timeline of major education reports from 1902 – 1979. Figure 2.3 displays a timeline of Education Acts from 1980 – 2010, followed by major education reports from 1980 – 2010 in figure 2.4. Appendix A sets out the complete list of documents reviewed and analysed for the case study.

## **2.6 The Taunton Commission**

In 1868, the Taunton Commission (Taunton, 1868) was tasked by the Government of the day to investigate and report on the state of secondary education in England and Wales. The commissioners looked at all the grammar schools as well as some private schools. Their recommendations were to structure the education system to mirror the class divides present at that time. For private schools, where children could study to the age of 18, a 'liberal' education would be provided that concentrated on the classics - Latin, Greek etc (Berghoff, 1990). This would prepare children for university and entry to the established professions e.g. law, politics etc. A second grade of school for the 'middle classes' would teach up to the age of 15 or 16 preparing the boys for entry to the armed forces, the civil service or 'newer professions'. The lowest grade of school - where children left at the age of 14 - would educate towards life as tradesmen, farmers, factory workers etc. (Jenkins, 2019).

The main purpose of education for the majority of children at this point was to ensure there was an adequate workforce. Education was about meeting the economic needs of the country. This was the establishment and forerunner of the tripartite organisation of schools. One very important recommendation of the commission was that natural science should form part of the curriculum as a matter of course. The commission also reported that there was a dearth of laboratory provision in the endowed grammar schools (Gillard, 2016).

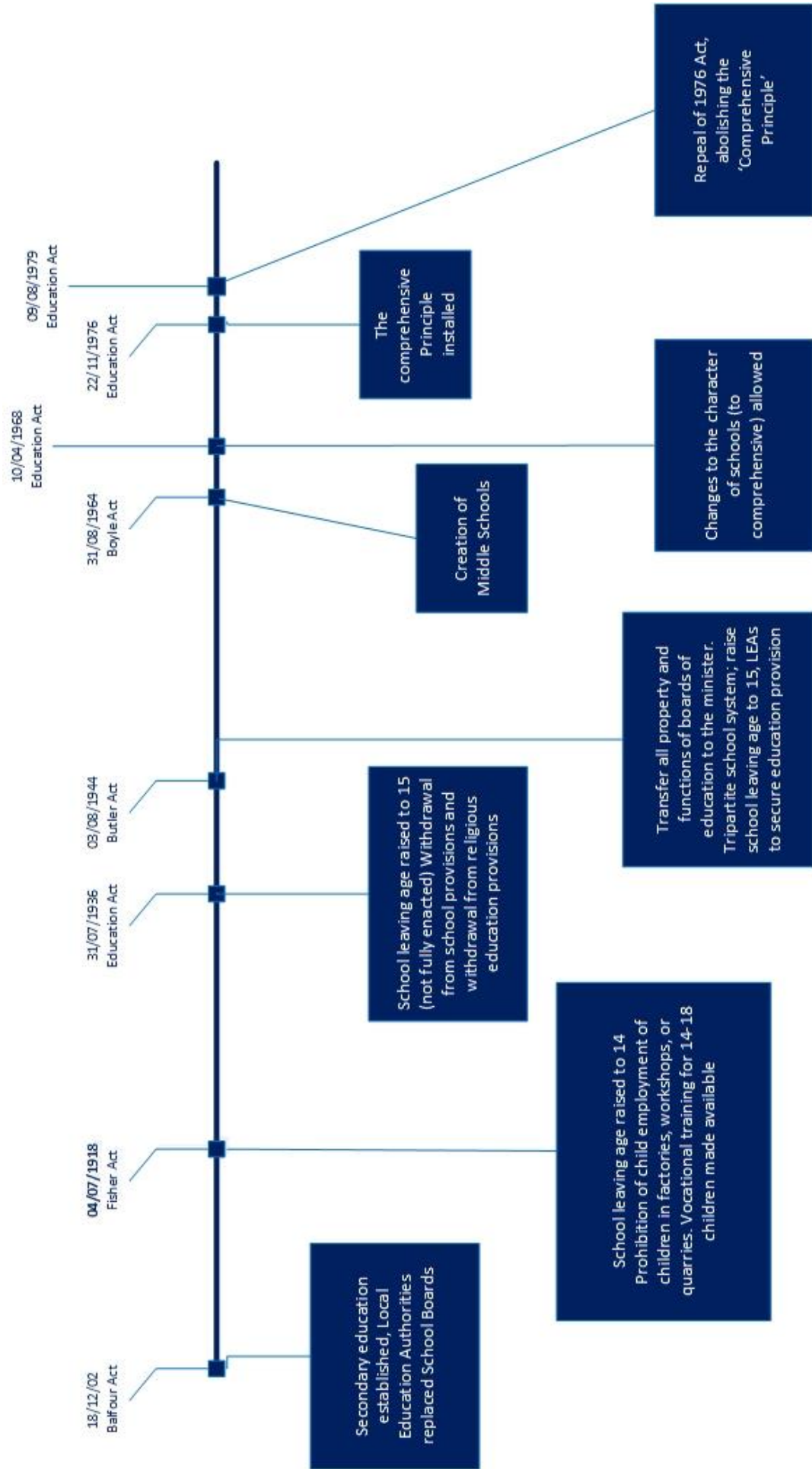


Figure 2.1 Key education acts from 1902 – 1979

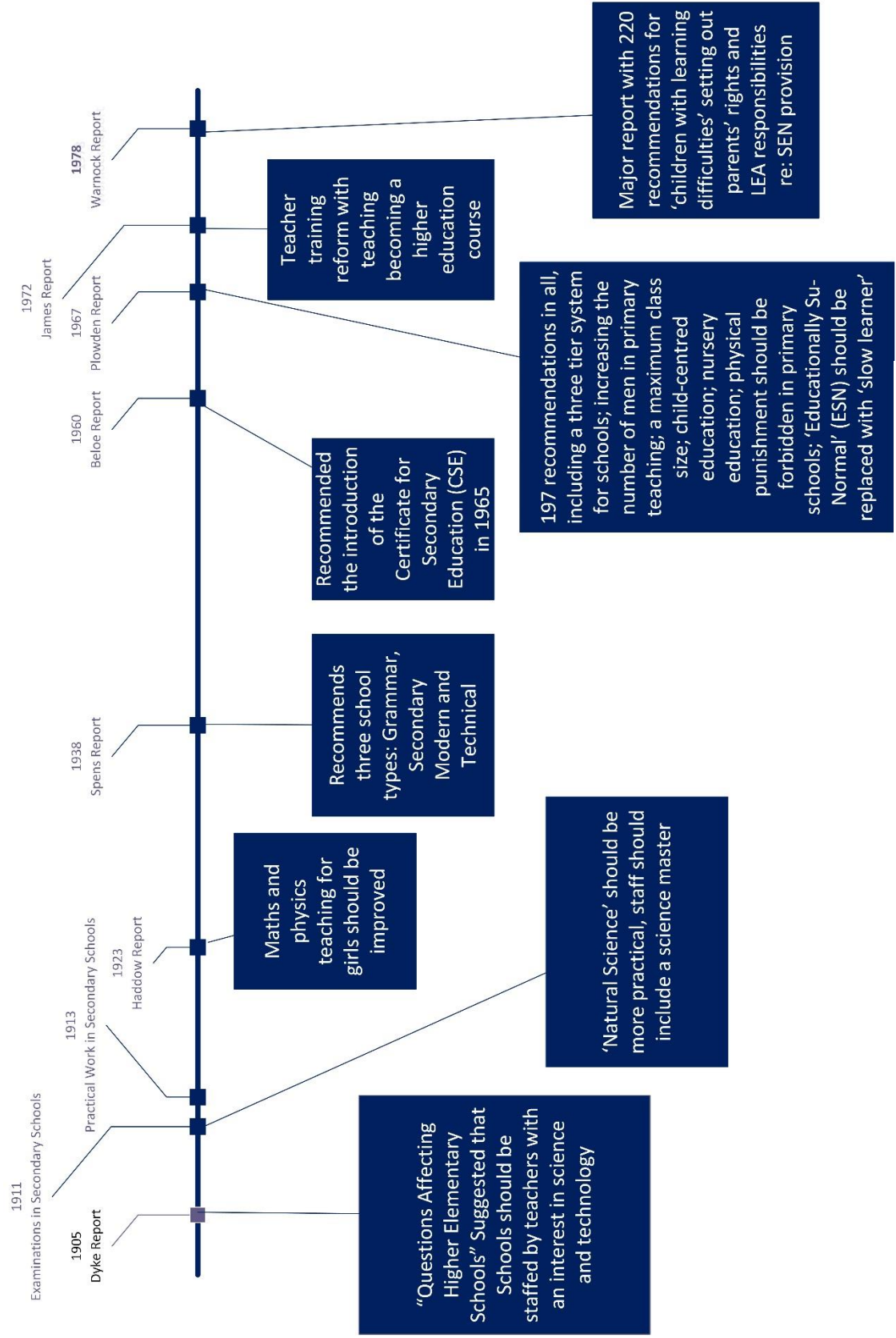


Figure 2.2 Key education reports from 1902 - 1979

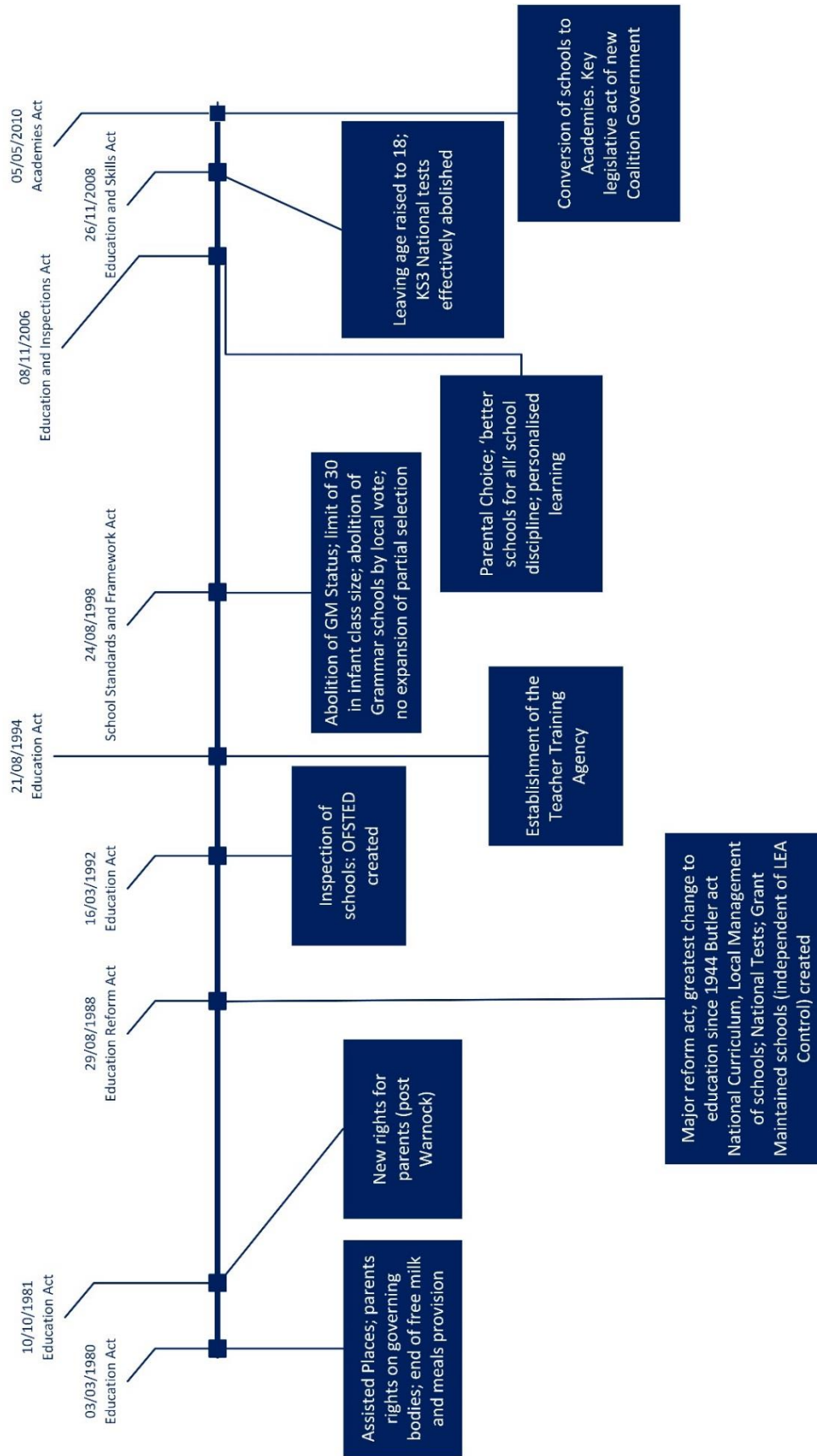


Figure 2.3 Major education Acts 1980 - 2010

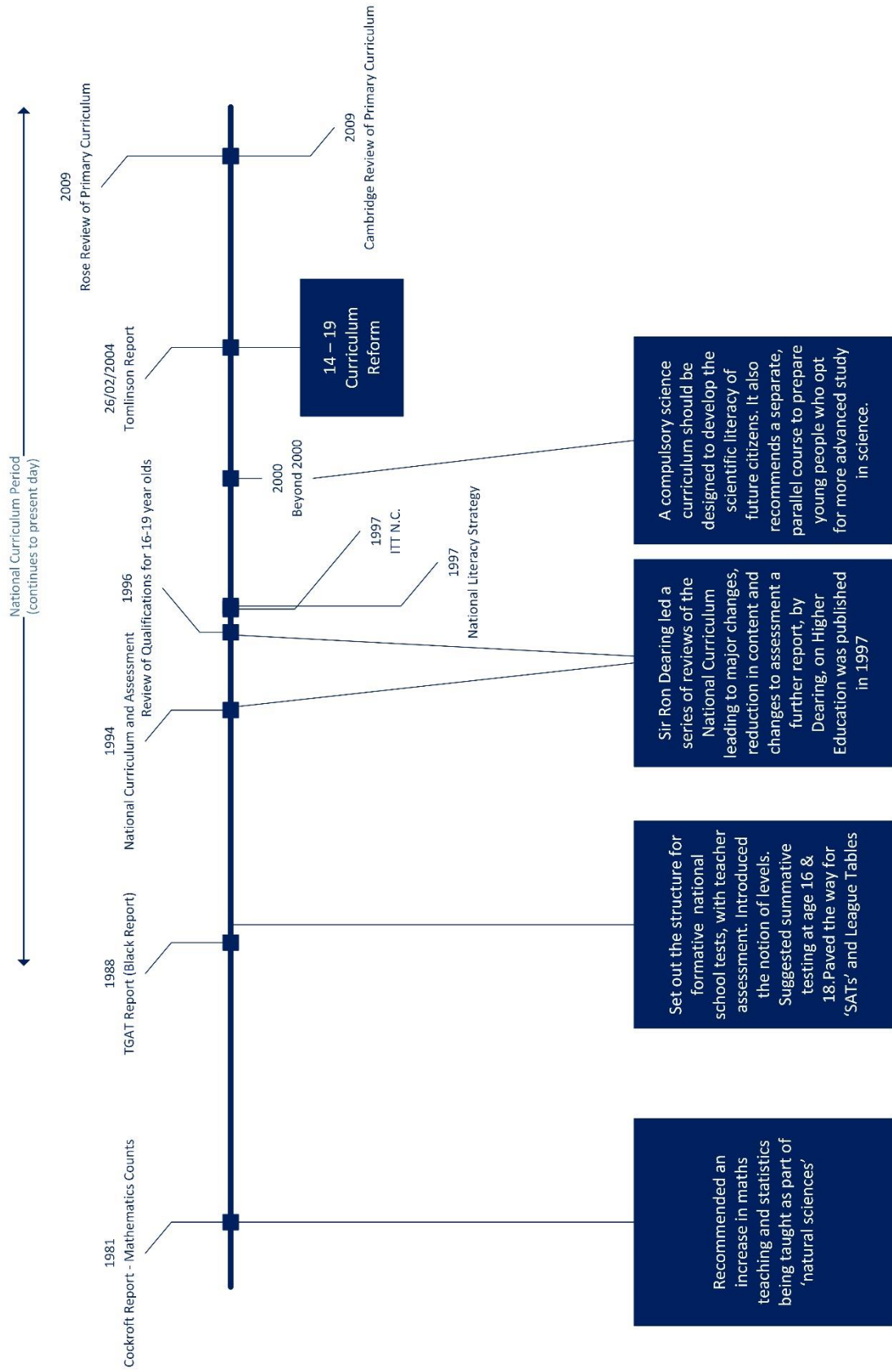


Figure 2.4 Major education reports 1980 – 2010

At Rugby School in Warwickshire practical science teaching began its life in a cloakroom in the Town Hall (Brock, 1977, p.605). The need for a sound scientific and technical education was not lost on Victorian Britain. After the Great Exhibition of 1851, which exposed Great Britain to fast improving technologies from other countries and how overseas technology was catching up with British technology, Government grants were provided for evening schools to provide a technical education (Acland, 1909).

In 1853, on the advice of Prince Albert, Queen Victoria's consort, the Department of Science and Art (DSA), the forerunner of the current Department for Education, was established to enhance both the provision of science and technical education, initially through evening classes, and the certification of teachers of science (Acland, 1909).

By the 1870s, just over half of the 128 endowed schools taught science and of those, only thirteen had a laboratory and a further five reported having some equipment for science experiments (Jenkins, 1979).

Although the 1870 act made elementary education compulsory, the number of schools offering elementary science dropped from 51 in 1884 to 32 in 1890. Between 1870 and 1895 the number of elementary schools increased from 8,798 to 19,739, but the percentage of schools offering elementary science had only increased to 2.4 percent by 1895 (Jenkins, 2019).

## **2.7 Political influence on early 20th Century science education**

The Balfour Education act of 1902 was the first act to cover post elementary education. Prior to this, elementary schools provided '*alternative kinds of education for different social classes*' (Acland, 1909, p.74), as noted above. Early in the 20<sup>th</sup> Century, Government acts and reports were shaping the provision of science in schools. This was a direct political influence, but the imposition of a political ideology was not necessarily always successful.

After the 1902 Balfour Act, schools were classified as either Division A or Division B schools. Jenkins (1979) provides a very comprehensive account of the development of science education in England. What follows is a summary of Jenkins findings.

Division A schools were science based, but also provided a general education. Thirteen hours per week was devoted to the study of physics, mathematics, chemistry, technical drawing and practical geometry. In addition, they devoted ten hours of instruction to general education, which included 'approved subjects' as well as English and a foreign language. In Division B schools, there was less content taught in science, maths and



technical subjects, usually up to nine hours per week. The funding of the Division A and B schools was very different. In 1903-4, 229 Division A schools received £137,568 in Government grants, whereas 253 Division B schools received £37,680. Additionally, grants were made available to Division A schools for scholarships and bursaries to encourage science teaching.

Such a move proved contentious politically. By 1904 the division system was abolished. In 1904, Government regulations for the first time defined a school as a place where a general education was offered to 16 and beyond. It also specified the subjects that should be on offer: English language and literature; at least one language other than English; geography; history; mathematics; science; drawing; manual instruction for boys; domestic subjects for girls; physical exercise and organised games (Jenkins, 1979; Lowe, 1984). This was the first 'imposed' curriculum on schools, but it was a curriculum only in name and at a superficial subject level. The content of each subject was not specified, unlike the NC of the 1980s and beyond.

As state education grew, the numbers attending schools increased. There was a need not only to specify what subjects should be taught, but also how schools and the school population should be organised. The state mirrored the prevailing class system in its organisation of schools and determined the subjects based on its economic priorities. The main priority was the need for a more educated workforce in an increasingly advanced industrial society and a more technologically advanced world.

In 1906, the Dyke report recommended that higher elementary schools should be staffed by teachers with an interest in science and technology. In 1913, the Acland Report on practical work in science recommended that 'natural science' should be based more on practical work (experiments) and that schools should include a 'Science Master' on their staff.

The 1918 Fisher education act, brought in at the end of World War 1, raised the school leaving age to 14 and prohibited child employment in factories, workshops and quarries. The effect of this act was to change the form of education in schools, which had been focussed on academic subjects, to introduce vocational training for young people ages 14–18. Political influence had broadened the curriculum and, at this point, created a vocational/academic divide within schools, which still creates political issues in the current education climate. The latest issue is the development of 'T' levels or technical qualifications, with the DfE rejecting calls to delay implementation over worries that the reform timescale was too ambitious (Greening, 2017; Belgutay, 2018; Owen, 2018).

In 1926, the Hadow report “*Differentiation of the Curriculum for Boys and Girls Respectively in Secondary Schools*” advised that the teaching of mathematics and physics needed to be improved for girls. It noted that Board of Education Circular 826, ‘*On the Curricula of Secondary Schools*’, stated that the course for the junior school, in which the average age of the pupils was between 8 and 12 years, must include for all pupils English, arithmetic, history, geography, drawing, singing, and physical exercises. No science education was specified.

By 1938, it was the structure of state schools that came under scrutiny. The Spens Report recommended that schools should be of three types, grammar, secondary modern and technical schools. This once more reflected the class system. Public School alumni still dominated the top professions and political posts. Grammar schools offered limited social mobility, but only to more able students (McCulloch, 2006). The recommendations of the Spens Report were realised with the seminal 1944 education act.

The 1944 Butler act did more than just seek to change the status of schools in creating grammar, secondary modern and technical schools, it also transferred all property and functions of the Boards of Education to the Minister in Whitehall. For the first time, education at secondary level was offered free of charge. Prior to this secondary level education required either a scholarship or payment. The act raised the school leaving age to 15 (and indicated it would rise further to 16, which it did, but only in 1972). It mandated that the Local Education Authorities (LEAs), created in 1902, would now be legally obliged to secure education provision for all children of school age. The 1944 act, in one sense, provided a template for the 1988 ERA as an act seeking to establish political dominance over schools e.g. how they are run and how schools should be designated. The 1944 act, however, did not affect the content of school subjects. This part of the curriculum was still under the control of teachers in elementary schools and for older children, the universities, via the many examination boards and a plethora of syllabuses for sciences that schools could choose to follow.

## **2.8 Educational influences on 19<sup>th</sup> Century school science**

One key supporter of 19<sup>th</sup> Century school science was T.H. Huxley who outlined his vision for science education and what should be taught. For Huxley, it was evident that the body of knowledge called science was too big to be delivered, even in a simplified form, to all children:

I do not mean that every schoolboy (sic) should be taught everything in science. That would be a very absurd thing to conceive, and a very mischievous thing

to attempt. What I mean is, that no boy nor girl should leave school without possessing a grasp of the general character of science, and without having been disciplined, more or less, in the methods of all sciences; so that, when turned into the world to make their own way, they shall be prepared to face scientific problems, not by knowing at once the conditions of every problem, or by being able at once to solve it; but by being familiar with the general current of scientific thought, and by being able to apply the methods of science in the proper way (Huxley, 1899, p.71)

What Huxley is arguing for here encompasses some aspects of the NoS. Huxley talks about the '*general character of science*' and sees '*scientific thought*', the logic of science, to be as important as the methods of science. How scientists work and how scientific arguments work is central to such a vision. Huxley goes on to describe the foundation on which a science education should be built:

I conceive the proper course to be somewhat as follows. To begin with, let every child be instructed in those general views of the phenomena of Nature for which we have no exact English name. The nearest approximation to a name for what I mean, which we possess, is "physical geography." The Germans have a better, "Erdkunde," ("earth knowledge" or "geology" in its etymological sense,) that is to say, a general knowledge of the earth, and what is on it, in it, and about it. If anyone who has had experience of the ways of young children will call to mind their questions, he (sic) will find that so far as they can be put into any scientific category, they come under this head of "Erdkunde." The child asks, "What is the moon, and why does it shine?" "What is this water, and where does it run?" "What is the wind?" "What makes the waves in the sea?" "Where does this animal live, and what is the use of that plant?" (Huxley, 1899, pp.71-72)

Huxley's vision was an approach to science education that fulfils the two aims outlined in the BAAS report; gaining an understanding of science knowledge and skills (a basic, pre-university science training), but also a public understanding of science, though with no reference to any moral and/or ethical aspects of science.

The idea of teaching separate subjects or disciplines within science does not appear to be an all-pervasive one stemming from the 19<sup>th</sup> Century. The physical sciences were essential to our country's economic welfare – an argument still put forward today (IoP, 2013) – but the rise of the sciences in education in the early part of the twentieth century was not universally welcomed.

As noted above, by 1904 the Division A and B schools were abolished and there was a redistribution of the time allocated for subjects. The thirteen hours for science was reduced to seven and a half. For other subjects, time was increased. For the first time, a minimum for the teaching of science was specified. No less than 3 hours per week of science teaching and it had to be theoretical and practical.

Biology, as a discipline, did not feature heavily. Its importance was linked to medicine. Often it was broken down further into botany, zoology and physiology, sub-disciplines of biology that serve those who are destined for medical training (Jenkins, 1979). By this point, the notion of three separate disciplines for science was, however, more or less in place.

## **2.9 The three sciences**

Although we traditionally think of 'science' as being the three core disciplines, five different disciplines are involved. Geology or Earth science and astronomy are incorporated into the provision of biology, chemistry and physics in modern science education.

It is not just the content of science that differs today from early science education. How we 'do' science has also changed. The traditional 'three' sciences are delivered in schools as a way of showing how science is carried out in the 'real world'. The subject content and the methods of science, in real life, develop and change quickly. The idea of school science as a mirror (albeit somewhat dim and distant) being held up to professional science is nonsensical. Calling the curriculum 'Science', as Jenkins (2007, p.265) observes:

allows science to be promoted as a coherent curriculum component and fosters an untenable but enduring notion of a unifying scientific method that ignores important philosophical, conceptual, and methodological differences between the basic scientific disciplines.

From an educational perspective we are in danger of promoting a vision of science that is very particular, but which does not necessarily match science in real life. The boundaries of the three sciences are blurred. For example, the boundary between biology and biochemistry, or chemistry, is difficult to find when considering cellular reactions in the process of photosynthesis. When we teach about the atom and atomic bonding, it's difficult to say categorically if this is pure chemistry or physics. Jenkins (2007) refers to the philosophical, conceptual and methodological differences between science disciplines and these represent the structure of the various disciplines. It is through a study of the NoS that such structures are established. This can subsequently help children understand the natures of the different sciences and thereby understand how physics arrives at its 'answers' and explanations, biology theirs and so on.

## **2.10 The quality of early science education**

Early science education in schools was not necessarily high quality, taught by specialists, or well organised. It has been described as chaotic (Timmons, 2001). It was not until the

education act of 1902 that the delivery of science in an organised way was really tackled. Even then, the teaching of science in elementary schools was rare. As Jenkins (2016) states online *'Far too little is known about the science education of most of the school population in the first half of this century.'*

Problems with the teaching of science were not restricted to a lack of understanding of what content should be taught, or that science should be delivered as 'pure science', free from moral, ethical or social considerations. There was also a distinct lack of specialist teachers who could deliver it in schools. Science teacher education was restricted mainly to London. Those who could freely enter teaching with little to no training were graduates of the natural sciences from Cambridge or Oxford and they were not in great supply. There were few textbooks, facilities were limited and it was expensive to deliver (Timmons, 2001).

### **2.11 Armstrong and the 'heuristic method' of science education**

H.E. Armstrong worked extensively to promote science education as a core subject in schools in the early twentieth century. Armstrong advocated the teaching of "the scientific method" (his term for practical, inquiry-based methods) in schools. At the time, he felt that his appeal would not be supported by many science teachers (Armstrong, 1903). Armstrong, a chemist by training, developed the 'Heuristic Method' for teaching science (Armstrong, 1902). This was a problem-solving approach. He developed his ideas on science teaching in the late 19<sup>th</sup> Century. He called for, and was influential in gaining, enquiries into the teaching of science in schools. As a result, changes were made to the DSA examinations to stress experimental work (Armstrong, 1973). The essence of heuristic teaching is that alongside the learning of factual knowledge on a subject, children were set specific problems that they needed to solve using various methods e.g. research in the library, trial and error, and experimental work. It was a form of discovery learning. Although it was widely implemented in the late 1890s it was not without its critics, who often misunderstood the method as being about children only learning by discovery and even making 'new' discoveries in science. This led to Armstrong (1973, p.5) having to defend his method robustly:

The greatest nonsense is talked about the impossibility of making students discover everything for themselves. No one asks that they should, or believes they can, only that they shall learn at first-hand how discoveries are made.

In the early 20<sup>th</sup> Century, science was a minority subject in schools. Its importance was heightened by the conduct of the First World War and the realisation that we needed physical scientists, chemists and mathematicians for our national defence. The period

between the First and Second World War saw a drop in education expenditure (Jenkins, 2019).

## 2.12 Organisational aspects of mid-20<sup>th</sup> Century school science

Following the 1944 Butler Act, a tripartite system (described earlier) was set up in England and Wales. The independent or private sector remained largely unchanged. A new system of examination, the General Certificate in Education (GCE) O level became the replacement examination for the existing School Certificate and Higher School Certificate. The new GCE examinations were based on discrete subjects rather than groups of related subject disciplines, which characterised the School Certificates. At this point the 'three sciences' were firmly established, though a 'General Science' examination at GCE O level was also available, but even that examined the sciences separately. From the 1950s to the early 1980s the teaching of the sciences in schools continued to evolve and become established as a core 'subject' (Jenkins, 2004).

In the 1950s the subjects taught were separate sciences in the grammar schools and, for those who were deemed able enough, in secondary modern schools (Jenkins, 2019). The general science approach was on offer for others. During this period there were many issues of gender inequality in the taking of the various disciplines (see table 2.1) e.g. boys predominantly took physical sciences and girls took biological science. The differences in outcomes between boys and girls in the 1950s show that although the entry of boys for physics O level was nearly eighteen times that of the girls, the pass rates were comparable. In both biology and general science girls outperformed the boys and only in chemistry did boys do significantly better than the girls.

Table 2.1 Entries for key O level subjects, summer 1951, by gender.

Subject	BOYS			GIRLS			TOTAL		
	Entries	Number Passed	% Passed	Entries	Number Passed	% Passed	Total Entry	Total Passes	Total % Passed
English Language	57,603	32,682	56.7	51,291	34,432	67.1	108,894	67,114	61.6
Physics	18,819	10,619	56.4	2,279	1,531	56.1	21,548	12,150	56.4
Chemistry	16,005	9,329	58.3	4,672	2,486	53.2	20,677	11,815	57.1
Biology	6,935	3,882	56.0	22,079	12,551	56.8	29,014	16,433	56.6
General Science	12,538	6,657	53.1	9,134	5,037	55.1	21,672	11,694	54.0
History	33,890	17,925	52.9	32,360	19,939	61.6	66,250	37,864	57.2

Source: (Jenkins, 1979, p.93)

In 1951 biology was a minority subject for boys, with only 6,935 entries. For girls it was the dominant discipline with an entry of 22,079. This is greater than the combined entries for boys in physics and chemistry. Biology became more important when it was needed for medical school. In some ways, this restricted the teaching of biology as a specialist rather than as a generalist subject (Jenkins, 1979) as entry to medical school was restricted to the highest attaining students.

### 2.13 Education reform from the 1950s–1970s

The school leaving age was raised from 14 to 15 in 1947, meaning many more teachers and buildings were required. An expansion of initial teacher training (ITT) alongside a building programme for existing schools (the Hutting Operation for Raising of the School Leaving Age (HORSA) and the Raising of the School Leaving Age (ROSLA) buildings). Many encouraged to take up ITT were ex-servicemen typically aged between 21 and 35 (Jenkins, 1979).

The new GCE examinations were introduced in 1951. O level and A level examinations were chiefly taken by the highest attaining children. Increasingly there was a need for some sort of examination for those children who, under the tripartite system, failed to secure a grammar school place and ended up in secondary modern schools, where far fewer children were entered for the academic O and A levels. This led to the introduction of the Certificate in Secondary Education (CSE) in 1965.

The increasing need for science teachers in this landscape is exemplified by looking at the GCE O level entries to the sciences from 1951 to 1962 (table 2.2). Looking at the increasing numbers of children overall tells one story about the need for increasing numbers of science teachers, but a closer look shows another interesting aspect of how science teaching was developing over the 1950s into the 1960s.

Table 2.2 GCE O level entries from 1951 - 1962

Year	General Science		Physics		Chemistry		Biology	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
1951	12,538	9,134	18,819	2,729	16,005	4,672	6,935	22,079
1955	15,359	9,811	32,495	4,662	28 044	6,910	12,872	34,080
1962	15,076	9,683	67,986	11,705	52 498	14,893	25,689	73,842

Source: (Jenkins, 2004 p.34)

Between 1951 and 1962, general science entries were very stable. Between 1955 and 1962 however, the number of girls taking physics and chemistry increased significantly. The increase was nearly 1½ times the number of entries for girls taking physics and over double for chemistry and biology. While the number of boys did increase from just under thirteen thousand to just over twenty-five and a half thousand, the number of girls taking biology went from just over thirty-four thousand to nearly seventy-four thousand.

In the mid-1960s, a change of Government to a Labour administration meant a major organisational change in schools as the tripartite system was abolished in favour of a new comprehensive system (Simon, 1992). LEAs were instructed to prepare for all schools to be comprehensive. Any new schools built had to be comprehensive. There was no statutory order to change the status or character of existing grammar schools, but many did. In some areas, e.g. Kent, grammar schools were kept and are still in operation. This change to comprehensive education facilitated a change in science education from all through separate sciences to more general, integrated or combined sciences, especially in lower secondary. Primary science was still largely ignored and there were no serious attempts to introduce science as a core primary subject.

As Jenkins (2004, p.33) says:

The expansion of school Biology teaching, from a relatively low base in the case of boys, is particularly noteworthy. So, too, are the relative numbers of entries in Physics and Chemistry for girls and boys. When compared with the gender distribution among all O level entrants, girls were considerably 'under-represented' in these subjects as well as in Mathematics. In some schools, including coeducational schools, girls were effectively 'debarred' from a full science course in the sixth form because they had done virtually no Physics or Chemistry in the main school or because they had failed, or did not take, Mathematics at O level.

In the 1950s there was what can only be described as a 'common understanding' of the subjects that should be taught in schools. For the formal GCE examinations, there were syllabuses that teachers followed, but these were nothing like the prescriptive documentation seen today. They were content driven, knowledge-based syllabuses (Jenkins, 2019).

## **2.14 The demise and rise of general science**

Between 1944 and the mid-1960s there was a 'general science' approach in secondary modern schools. Being taught general science did not necessarily mean an even split of all sciences being taught. It was still predominantly physics and chemistry (Jenkins, 1979). The move to expand and have general science as the dominant form of science



education was also being questioned, e.g. by Connell and James (1958) in a report on the teaching of science which concluded that:

An improvement in...school science teaching is a requirement for the continued existence of this country as a leading scientific and industrial nation. As a first step in this direction general science... should be abandoned (cited in Jenkins, 1979, p.99)

This report had a view that separate sciences were essential to produce the scientists necessary to ensure our international economic success. Despite this, the next three decades saw an unprecedented period of science education curriculum reform (see figure 2.5): the Nuffield Combined Sciences Project – instigated in the 1960s but published in the 1970s; the Schools Council Integrated Science Project (SCISP) developed in the 1970s; the Secondary Science Curriculum Review (SSCR), which funded, for example, the Children's Learning in Science (CLIS) project and SATIS (Science and Technology in Society). These effectively covered the full secondary age range with Nuffield catering for 11- 13-year-olds and SCISP developed to meet the needs of able 13-16-year-old children, leading to a double certification science O level. The SSCR was probably the most ambitious of the projects, set up by the then Government that desired a *'balanced and effective science curriculum for all pupils in secondary schools'* (Layton, 1984, p.125).

The SATIS project (SATIS,1986) is worthy of note as its purpose was to provide teachers with lessons that would relate school science to its social and technological context. In one sense, the lessons were delivering aspects of the NoS (specifically with respect to human endeavour and the social context of science). The SATIS project reflected the way Government policy was moving with respect to the provision of broad balanced science for all (DES, 1985) and came from a working group convened by the Association for Science Education (ASE).

The reforms were being driven by science education experts rather than top down reform driven by university academics with science expertise, who may not have experience or expertise in science teaching and learning in schools. Primary science was still, as it had been for many years, a neglected subject, though attention was being turned towards the primary sector.

Since the inception of science in schools, the outcome has been geared towards a utilitarian purpose; we teach science to ensure a good supply of scientists and technologists. An essential part of this approach is the idea of "the scientific method" (TSM).

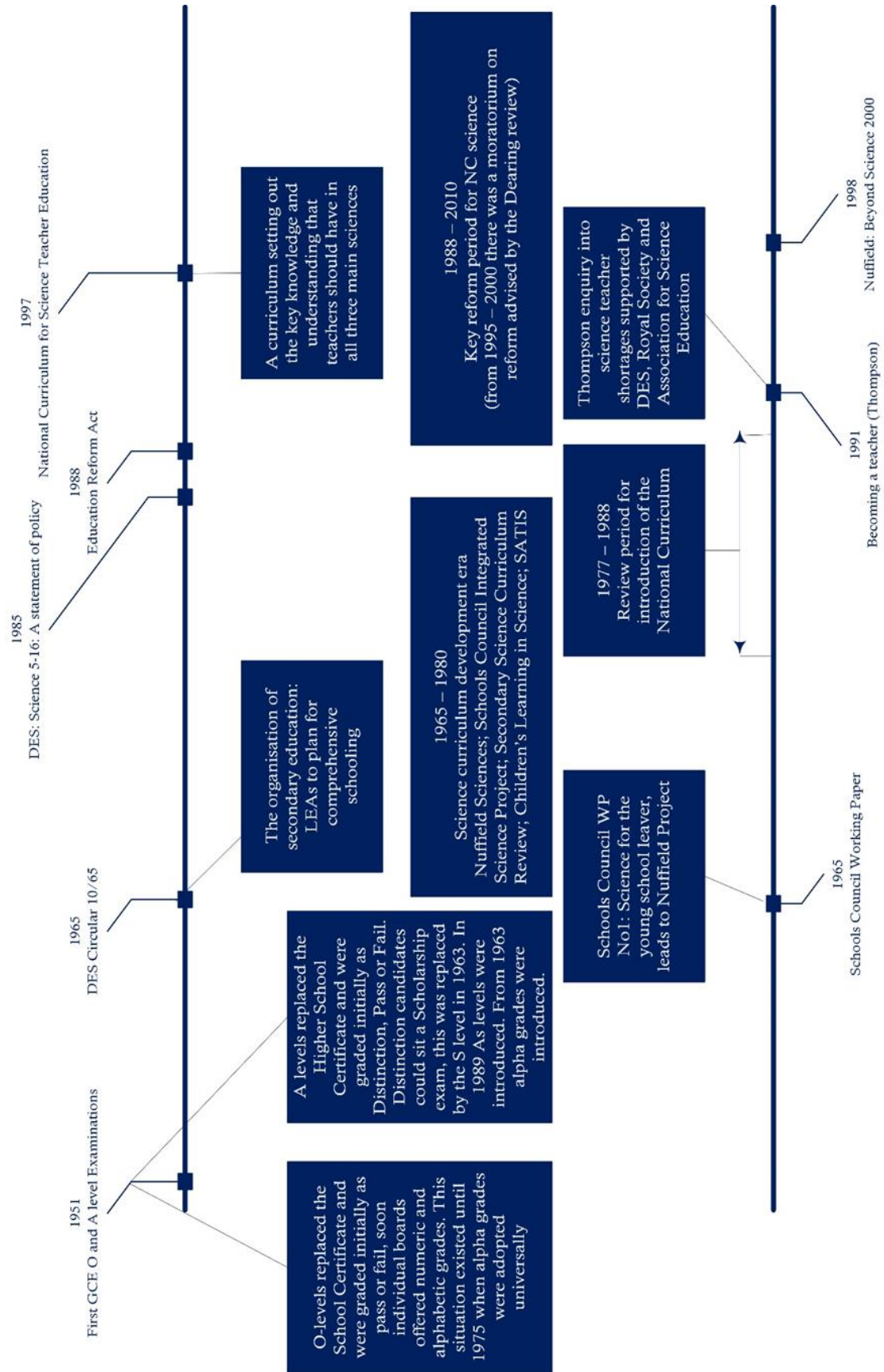


Figure 2.5 Major developments in science curriculum reform 1960 - 2010

During this period, in common with the earlier approaches to science education, there was a push from central Government. The driving force for educationists was the development of scientific literacy through a curriculum that delivered science that, rather than separating out the various disciplines, tried to make them more integrated and coherent. This is one of the tensions between Government policy and influence over educational influence. By the mid-1970s it appears that the time was ripe to consider a more formal approach to a centrally driven curriculum. The time was right to consider a move to a National Curriculum and a more centrist vision for education.

### **2.15 Initial teacher training and the supply of science teachers**

With regard to organisational influences, I should now consider the role of initial teacher training (ITT). Regardless of how the curriculum is organised - as combined, general, integrated or separate disciplines - it needed to be enacted and delivered (ideally) by science teachers. What follows is a brief overview of changes in ITT since the Second World War.

In the 1950s, teaching was not a graduate only profession and was not a profession where a formal teaching qualification was required. Grammar schools routinely employed graduates as teachers with no teacher training or teaching qualification, but were finding recruitment hard. Although graduates training to teach and entering the profession was rising, these were mainly arts graduates. The demand for science and mathematics teachers was high, but the supply did not sufficiently meet demand. The Government had a programme of national advertisements and key actions, e.g. extending the retirement age and paying bursaries to teachers teaching advanced subjects, in order to try to meet a rising demand (Jenkins, 1979). Secondary modern schools often had no qualified science teacher (Jenkins, 2004).

Colleges, specifically for the education and training of teachers, were long established but were not seen as a full part of the Higher Education system, as noted in the Robbins Report (1963, p.107):

The Training Colleges in England and Wales and the Colleges of Education in Scotland alike feel themselves to be only doubtfully recognised as part of the system of higher education and yet to have attained standards of work and a characteristic ethos that justify their claim to an appropriate place in it.

This did not mean that universities were not involved in ITT. As the McNair report of 1944 documents, there were, at that time, 83 teacher-training colleges and 22 university teacher-training departments. The regulations for teaching qualifications were, however, inconsistent, e.g. certified teachers in elementary schools, who overall were not holders

of a degree, were required to undertake a one-year probationary period. Secondary teachers, whether certified or employed as subject graduates, did not. A move from secondary teaching to elementary teaching paradoxically would then require a probationary period (McNair, 1944).

During the 1950s and 60s there was little Government direction in ITT. The Robbins Report (1963) called for the renaming of Teacher Training Colleges as Colleges of Education and introduced a new 4-year Bachelor of Education (BEd) degree. The publication of the Plowden report of 1967 into primary education identified issues in the training of teachers and called for an inquiry, leading to the James Report (Plowden, 1967).

### **2.16 Teacher education and the move to graduate status**

The James Report (1972) looked specifically at teacher training and determined that teachers of specialist subjects at a secondary or higher level should be graduates. The report was not universally welcomed and the response from Government took some time. Many of its recommendations were never fully implemented or were overtaken by the proliferation and establishment of new universities, e.g. a Diploma in Higher Education, a 2-year qualification, was never realised. One of the core recommendations of the James report, made within the structure of a 3-cycle training for teachers, consisted of initial higher education, followed by professional training and induction and finally in-service education and development. This does characterise the ITT and new teacher scene to this day (Taylor, 2008). During the period leading up to the introduction of the NC, ITT was undergoing major change and reform. The success of any future curriculum would reside in the preparedness of the teachers to teach that curriculum.

### **2.17 Summary**

In the early 19<sup>th</sup> Century, science education was neither compulsory nor common. The curriculum in schools was a matter for the school and there was little to no political influence on schools. Organisational and educational matters were also the responsibility of the schools, though in many instances, the Church – the main provider of educational opportunities in England – oversaw this.

A 'good education' was not seen necessarily as emanating from a rounded curriculum that delivered a broad and balanced education in different subjects. In the public schools, it was heavily based on a study of classical subjects such as Greek and Latin. Education in such schools was geared towards the elite and towards the established professions such as law and politics. University entrance was also for the elite.

Science was not considered an important core subject, but the Great Exhibition of 1851 highlighted how many other countries were rapidly advancing in science and technology, challenging Britain's economic, scientific and technological superiority. A need for science education was identified and the DSA was set up to facilitate this need. The BAAS report of 1867 confirmed the continued need for science to be part of the school curriculum. Politically, once the 1870 Forster Act introduced compulsory schooling for elementary education, the state became firmly involved in the running and organisation of schools. Over time the compulsory education system expanded into secondary schools, but how schools were organised was principally based on the prevailing social class system.

The driving force for science education was a utilitarian one, which focussed on ensuring a supply of scientists and technologists for our economic wellbeing as a country. Although 'public understanding of science' was recognised, e.g. by Huxley, the overwhelming educational influence, especially with Armstrong's heuristic movement, was still about knowledge and skills and the processes of science over an understanding of the structure of scientific subjects or the NoS.

The 1944 education act reinforced the prevailing social class system found in society within the state school system and with it a belief that the academic subjects were only for the highest attaining children, with vocational subjects for the lower attaining or lower classes. A common purpose of state education was a preparation for being a useful contributor to the workforce and a contributor to the economic well-being of the country. Educationally, universities still had control over the content of the curriculum through the various examination boards.

The NoS was a significant addition to the core science knowledge that characterised pre-SNC, where core knowledge concentrated on scientific concepts such as forces, atoms, evolution, organs etc. In addition, it focussed on experiments, rather than scientific inquiry, to demonstrate key knowledge. In the development of the SNC, there was a clear educational influence that saw an understanding of the epistemology of science as important. In the consultation document (DES, 1988b) a full attainment target was devoted to 'The Nature of Science', AT22. Even after this draft document was revised, the NoS was retained as a full attainment target, AT17. By 1991, the NoS had been 'demoted' to the programme of study and it was no longer a full attainment target. The NoS had lost its educational imperative to a need to reduce content and provide a curriculum that teachers could more easily enact. Internationally, and within the UK, the NoS was still an important underlying educational priority as will be seen.

## Chapter 3

### Literature Review

The three broad themes within this case study focus on the political, educational and organisational influences on school science. Chapter 2 demonstrated that these are not new issues and they influenced the curriculum from its earliest days. Historically, political influence on the curriculum had not been intense. With the introduction of the NC, the role of politics in how the curriculum was developed and put in place played a much bigger part. One major aim in introducing a NC was accountability – how to make schools and teachers accountable for what they teach and for educational outcomes. This was measured using tests and public examinations. One major shift with the introduction of the SNC was that for the first time there was a political influence on the content of the curriculum the so-called ‘secret garden’ (see Chapter 5) as well as direction on how to teach the content, which in my view is analogous with the government taking on the role of the Head Gardener.

Any review of literature is selective. For this research the following selection criteria were applied when examining literature to inform this case study. The literature was guided by contributions from:

- 1) Key philosophers, historians and educationists who have written on the NoS were included e.g. Popper, Kuhn, Feyerabend, Lakatos. Their inclusion represents a range of views on the subject and, therefore, a balanced treatment of their conceptions of the nature of science and the scientific method;
- 2) Educationists and philosophers who have written on knowledge, beliefs and how teachers translate their knowledge into practice were also included, e.g. Russell, Shulman, Polanyi;
- 3) Researchers on the NoS, how it is understood by education practitioners were also included, e.g. Lederman, Brickhouse, Matthews, Smith, Cobern, Abd El Khalick, Taber etc.;
- 4) Researchers on Scientific Inquiry and ‘scientific methodology’ were also included, e.g. Bauer, Shamos, Feyerabend, Lakatos etc.;
- 5) Briefly, some research on the NoS and scientific literacy is looked at as achieving scientific literacy is often cited as a reason for the inclusion of the NoS in the curriculum;
- 6) Curriculum theorists and researchers e.g. Posner, Goodson etc.
- 7) Authors on the history of science education and the political influences on the national curriculum e.g. Jenkins, Whitty, Ball etc.

#### 3.1 Literature search process

Major databases, e.g. ERIC; JSTOR; SCIENCE DIRECT; WEB OF SCIENCE; GOOGLE SCHOLAR were searched using key words with Boolean searches (AND, NOT, OR) to

identify and filter relevant articles. Key word searches included: *nature of science*; *scientific method*; *teacher understanding*; *teacher knowledge*; *teacher belief*; *science curriculum*; *inquiry teaching*. Date restrictions were used to narrow down publications that appeared in the period 1980 – 2018 (just prior to the case study time frame to the present day). Searches were then widened to ensure any important papers or books with particular significance, or significant authors, were included. Author searches were also undertaken to identify series of articles by the same author on any of the relevant topics.

Once a body of literature had been established, the topics for the literature review emerged and were matched against the research questions. After an initial draft of the analysis chapters had been completed, the literature review was returned to and selections modified in the light of the emerging conclusions. What follows is the redrafted and final selection of literature.

### **3.2 The history of the nature of science in science education**

General reading about the NoS over the past 50 years or so reveals issues in coming to any agreement about what the NoS may be and whether it is even helpful to think of one definition of the NoS. Philosophers of science, physicists, biologists, chemists, science educators etc. all have varying definitions of the NoS, which serve their purpose and discipline. To establish a baseline for the literature review I looked at the history of the NoS in science education and read one of the first academic treatments on the subject by James T. Robinson from Columbia University (Robinson, 1968; 1998).

#### **3.2.1 Robinson's views on the nature of science in science education**

Robinson noted that the relationship between the NoS and the teaching of science had not been explored in any depth before the 1960s, yet it was recognised that the relationship was an important one for teachers (Robinson, 1968). Having discussed the issue of the exponential growth in scientific knowledge (which is still an issue for the current curriculum) a key question for the day was "What 'scientific knowledge' is necessary for all our children?" Science teachers, it was recognised, cannot hope to cover all scientific fields of enquiry, neither can they design a fully inclusive curriculum that contains a set of scientific concepts, theories and ideas which all scientists would agree were 'essential' for every child to know and understand, but something that could be delivered was an understanding of the NoS. In his book, Robinson covers a wide range of issues, such as philosophy of science, language and science, the nature of physical reality and concepts in biology, before summarising his view of what understanding of the NoS is needed to promote 'scientific literacy' in any science curriculum.

Robinson (1968) admits that any definition of the NoS which applies to all scientific disciplines required a high level of abstraction. He argued this is relevant to science education as a starting point for educators to examine exactly what is meant by 'science'. Today, we have a curriculum in UK schools nominally called 'science'. This consists of five separate science disciplines, chosen mainly because of historical expediency, as outlined in Chapter 2. Such a discussion on the meaning of science should take place if teachers of the sciences are to grasp what the defining commonalities between the sciences are and thereby work out the differences.

For Robinson, scientific thought operates on two levels, the empirical and the rational. At the rational level, methodological procedures will allow the development of systems of constructs, which can be linked to observables. These form the basis of theories. The goal of science, according to Robinson, was the development of a fully axiomatic system of theories. Achieving this is difficult, if not impossible. As the constructs are made, they move away from the '*plane of perception*' (Robinson, 1968, p.15) that is, from the observed reality towards our theoretical constructs of that reality. This neatly illustrates an issue in science teaching. When we conduct experiments, we rarely get the answer that the theory will predict. As we will see later, this is an issue for some people, as one of the interviewed science teachers found this aspect of science frustrating, leading to a path studying theoretical physics, so that the uncertainty of experimental physics was not an issue.

The physical sciences, Robinson states, are characterised by deductive theories and a deductive approach. At the high end of explanation (theories) and descriptions (laws) in the physical sciences, logico-mathematical systems tend to dominate and account for the proliferation of 'laws' in physics. Biology, on the other hand, is more observationally descriptive and correlational. There are few areas of biology that are truly logico-mathematical in character.

One of the few laws which does operate in biology is the law of independent assortment (though it should be noted that this sometimes referred to as a principle rather than a law). It is a general description in Mendelian genetics that does have a basis in mathematics. The 'problem' of biology is that traditionally it has been a descriptive science, which then leads to taxonomic classification. Our theories in biology, rather than being deductive or arising from a deductive methodology, are usually inductive – moving from the general observations in nature to specific unifying theories e.g. the theory of evolution developed from observations of the relationships between species of plants or animals etc. in nature.



Robinson concluded that the NoS can contribute to the development of a curriculum for science and that this, in turn, contributes towards scientific literacy. How we organise our thoughts in science are also key to his view of the NoS. He characterises the nature of scientific thought as '*constructionist*', that is, it is a characteristic of human beings to be organised, to develop '*ordered systems of explanation*' whose validity is confirmed through experimentation (Robinson, 1968, pp,123-125).

Robinson's work exposed some key ideas when considering the NoS in relation to science teaching and learning. He demonstrated differences between the sciences and how this can lead to problems when trying to apply one consistent view of the NoS to all science disciplines. Superficially, science in schools is presented as a coherent 'subject'. For example, teachers are often called 'science teachers' and within state education and independent state education they are often required to teach all the sciences to at least the end of Key Stage 3 regardless of their original subject specialism. This is also often the case at Key Stage 4, either due to organisational issues such as timetabling or a lack of specialist teachers in the physical sciences. A failure by teachers to fully appreciate or understand the differences in the operation of the different sciences at an epistemological level adds to the lack of coherence between the sciences. One obvious solution would be to ensure a good understanding of the NoS by all teachers of sciences and the explicit teaching of the NoS to help children understand the similarities and differences in the sciences, which may have the effect of enhancing coherence across and within the curriculum, though further research would be needed for this to be established.

It must be noted that in the fifty years since the publication of Robinson's article and book, the growth in scientific knowledge has, as he predicted, been exponential. There has also been a proliferation in the disciplines and sub-disciplines of science, such that the idea of the 'three sciences' i.e. biology, chemistry and physics, as the common disciplines taught in school is becoming more problematic. His view of the NoS as being empirical and rational, proceeding through mainly deductive processes for the physical sciences and inductive for the biological sciences is also tempered with consideration of the social context of science and the past. As Robinson (1968, p.127) put it:

It thus becomes essential that education in the sciences provide ways for individuals to learn that the very "seeing" and "recording" that man (sic) does have been influenced by his (sic) past. The signs which denote phenomena are themselves inventions and are not the phenomena.

### 3.3 Defining the nature of science in science education

Lederman (1992) and subsequent co-workers (Lederman *et al.*, 2002) contend that a simple definition of the NoS is not possible. Alters (1997b) conducted a study of philosophers of science on whether the conceptions of the NoS as held by science educators were also held by them. His conclusion was that the philosophers surveyed:

express major criticisms of some of the basic tenets of the criteria and that different philosophers of science vary on their views about the tenets of the NOS. Therefore, many of the existing NOS tenets, which are commonly taken as factual, must be reconsidered. (Alters, 1997b, p.4)

Alters' methodology and conclusions were disputed by other workers in the field, including Smith *et al* (1997, p.1102), who stated that: '*Too much is being made of disagreements concerning the NOS*'. Alters (1997a) responded to these criticisms by dismissing them as an attempt to defend the critics' own '*ideology*' concerning the NoS. The question raised here is what 'ideological' definition of the NoS is being put forward? If we view several science curriculum documents, we should be able to determine what science is being taught as consensus science through the frequency of topics e.g. evolution is a consensus topic common to many school science curriculum documents in many countries. As Stanley and Brickhouse (2001, p.47) observed though:

Typically, the school science curriculum contains only ideas on which there is very widespread consensus; that is, they are uncontroversial in the field. However, although almost everyone agrees that we ought to teach students about the nature of science, there is considerable disagreement on what version of the nature of science ought to be taught.

In later work, Lederman (2007, p.833) did attempt a general definition of the NoS as '*the epistemology of science*' that is, science as a way of 'knowing' along with the values and beliefs inherent to scientific knowledge and its development. He also provide a useful summary of characteristics for the NoS for science education purposes. His six characteristics encompass what students should glean from any teaching that purports to cover the NoS. He grouped the statements into four major categories:

- The philosophy of science
- Scientists and their work
- The characteristics of scientists
- The history of science

Abd-El-Khalick, Bell, and Lederman (1998, p.418) came to similar conclusions on both the disagreements and that a consensus on some NoS statements could be found and utilised in school science education:

The disagreements that continue to exist among philosophers, historians, and science educators are far too abstract for K–12 students to understand and far too esoteric to be of immediate consequence to their daily lives. ... There is, however, an acceptable level of generality regarding the NOS that is accessible to K–12 students and also relevant to their daily lives ... at this level of generality, virtually no disagreement.

Lederman *et al* (2002, p.499) later confirmed this view:

some important aspects of NOS are not controversial... scientific knowledge is tentative; empirical; theory-laden; partly the product of human inference, imagination, and creativity; and socially and culturally embedded. Three additional important aspects are the distinction between observation and inference, the lack of a universal recipe like method for doing science, and the functions of and relationships between scientific theories and laws.

In setting out these general characteristics of the NoS we have a workable model that can be applied to a science curriculum.

### **3.4 Scientific literacy and the nature of science**

A core aim of many curriculum documents in science is to deliver 'scientific literacy' (Nelson, 1998; Roberts, 2007; Lederman *et al.*, 2013; Roberts and Bybee, 2014). How this is defined varies considerably. A simple agreed definition of what scientific literacy is and what it might look like in practice is missing (DeBoer, 2000).

One issue is the subtle, yet important, difference between science literacy and scientific literacy (Roberts, 2007; Roberts and Bybee, 2014). Science literacy is understanding science – it is being able to understand the key concepts taught in school science, such as photosynthesis, forces or atoms. Scientific literacy is an appreciation of science and how science operates, what science 'is' and what is not science – in other words knowing science and knowing about science.

The importance of scientific literacy resides in how we see the purpose of science education. Simply knowing facts in science or understanding key concepts will enable you to work in the field of science. You will be able to function in a utilitarian sense as a scientist. Scientific literacy is being able to understand how science operates in wider contexts, including societal contexts, and understanding that science can and does influence our lives and the lives of others. If a curriculum is predicated on the former, then it may not develop the latter even if one of the stated aims is to develop scientific literacy.

Roberts (2007, p.729) suggests that science literacy and scientific literacy are the overarching concepts that define '*what should constitute the science education of all*

*students.* A third term often 'mixed in' with scientific literacy, is 'public understanding of science'. This term is less evident in the literature currently, perhaps, as Roberts suggests, because the term itself begs the questions 'which public?' and 'what understanding?' One noticeable exception to this is the application of the term to adult learning by Falk and Dierking (2012).

Over time, as demonstrated by Roberts (2007) and earlier by Shamos (1995), the term scientific literacy has changed from early use within science policy, from being about the intersection of science and society, to finally, in some of its latest guises, being about the knowledge, understanding and implications of science within society. In describing what scientific literacy is, work by Shen (1975) was developed and adapted by Shamos to describe three levels of scientific literacy:

- 1) **Cultural Scientific Literacy** – the easiest, lowest form of scientific literacy. It is key background information that we should all have about science, a lexicon of scientific terms that should be familiar to all.
- 2) **Functional Scientific Literacy** – at this level the lexicon is supplemented by the ability not just to know the terms, but to be able to communicate meaningfully using the terms correctly.
- 3) **“True” Scientific Literacy** – this subsumes dimensions one and two and is characterised by the person being able to not only communicate meaningfully but understand how scientific concepts have arisen and changed over time and how science operates (e.g. with respect to scientific investigations and experimentation).

Bybee (1997) took the definition scientific literacy even further and, like Shamos, thought about it in terms of the relative knowledge and understanding required for different levels of scientific literacy (figure 3.1). This conception of scientific literacy, while the most complicated in the number of levels of 'literacy', is the most comprehensive. It combines not just science literacy – the knowing of science - but the interactions of science and society and the interactions between scientific disciplines. For this reason, it is my preferred vision of scientific literacy. What Bybee does not look at is the move between levels and what that means in terms of the 'amount' of knowledge or understanding a child would have to have (or an adult for that matter, as the scale could equally apply to adults as well as children) to move from one level to the next. These levels are unlikely to be 'equal' in terms of the volume of knowledge or the skills and the depth of understanding that need to be achieved to say that the level has been attained.

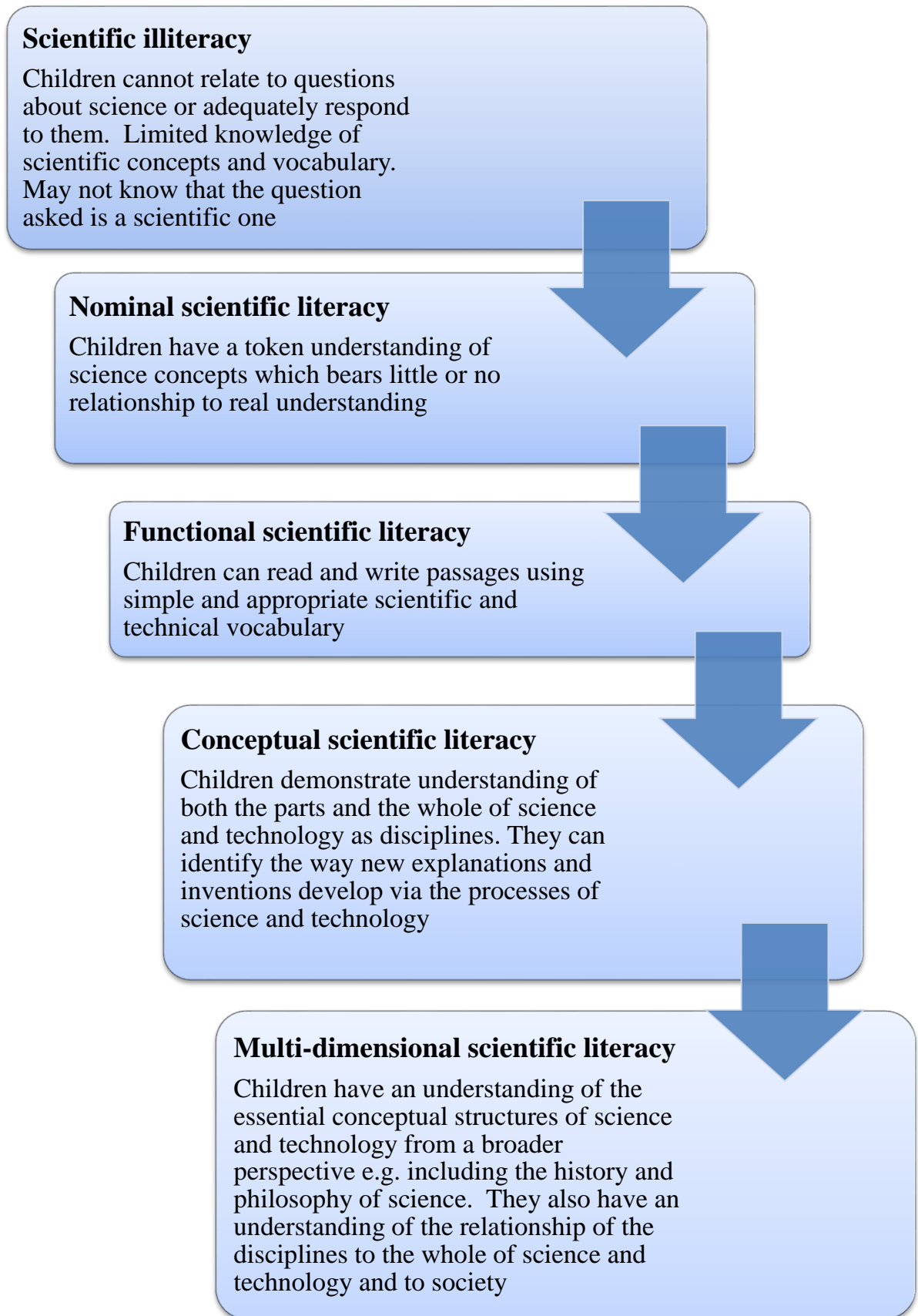


Figure 3.1 Scale of scientific literacy Adapted from Bybee (1997)

The decision on the appropriate level would likely rest with the professional who is assessing the level of scientific literacy of an individual. It may also be the case that the level of scientific literacy will not be equal across all scientific disciplines, given the divergence in the knowledge requirements of each discipline. Where the scientific disciplines are specified, and the gross content known, for example within a science curriculum, then any level is more likely to be able to be applied across the disciplines covered by the curriculum. This application of levels of scientific literacy is analogous, though not directly equivalent, to the levels initially given to the various subject attainment targets within the NC for Science as a means of assessing the knowledge, understanding and skills of the children.

For Shamos, the ‘myth’ of scientific literacy was that it could be achieved for all. He saw it as ‘...*little more than a romantic idea, a dream that has little bearing on reality*’ (Shamos, 1995, p.215). He also saw scientific literacy in a school science sense as quite different from adult scientific literacy. He contended that even if we did achieve scientific literacy in school science education, there is no guarantee that those who achieved it would remain scientifically literate as adults. In this sense, Shamos is identifying a difference between ‘public’ understanding of science and scientific literacy. He also questions the use of the generic term ‘public’ saying that different portions of the ‘public’ would have different views on how scientific literacy is defined. He ends by calling not for ‘scientific literacy’ per se, but ‘scientific awareness’ to engender an appreciation of science in its widest sense.

An issue we meet if we adopt this strategy is how to deliver this in an education system that requires not only scientific literacy (and appreciation) but a utilitarian approach to science education. The utilitarian approach is designed to deliver enough scientifically knowledgeable students (i.e. students with a high degree of science literacy) who can further their understanding at a higher level and become what Bybee (1997) would call ‘multi-dimensionally literate scientists’, who can then contribute to our economic wellbeing as a country.

Scientific literacy, as discussed above, requires a broader understanding of science than just knowledge of scientific concepts. The reason for wanting a scientifically literate population is to allow people to come to informed decisions about ‘*personal and societal problems*’ (Lederman *et al.*, 2013, p.138).

Lederman contends that there has been a failing in science education to ensure that an adequate understanding of the NoS and Scientific Inquiry (SI) has been communicated to teachers. There has also been an assumption that simply doing science – that is,

taking a pedagogical approach of 'hands-on' science through investigation and direct instruction of scientific concepts – that this will translate into an understanding of the NoS. Holbrook and Rannikmae (2007) assert that science education is building on logical positivism, that is, information and concepts are theoretical components comprised of observational language. The teaching of science is about relating phenomena to theories and supporting these with further observations. This is a very hypothetico-deductive approach that results in the teaching of science as simply the reinforcing and rationalizing of experimental results. This, they argue, reduces the relevancy of science for children. I would argue that it also does not allow for an understanding of the nature of science as we conceive of it currently. Holbrook and Rannikmae (2007, p.1348) also warn of the danger of a curriculum that focuses on content delivery over understanding:

there is a danger that an over-emphasis on content overshadows the acquisition of educational goals and thus inhibits the promotion of multi-dimensional levels of scientific literacy

A further issue is the conflation of the NoS and SI as being the same.

### 3.5 Scientific inquiry and the nature of science

The problem with a logical positivist position is that it will not encompass aspects of the NoS, such as creativity, imagination and the social/cultural embedding of knowledge. Teaching science from this perspective cannot achieve an understanding of the NoS. Such a pedagogical approach also emphasises SI, the processes and skills of science, defines how science obtains its evidence for the concepts being taught. While this is partially true, it neither reflects the reality of the NoS nor how science happens in reality. Figure 3.2 sets out a position where the teaching of science and scientific inquiry leads to science literacy, but not scientific literacy as the NoS is missing from the equation. Figure 3.3 describes a model that should be adopted if the aim of science education is to achieve scientific literacy.



Figure 3.2 Delivering science literacy through teaching *in* science

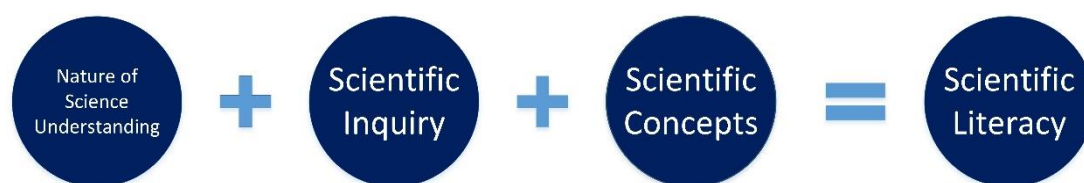


Figure 3.3 Delivering scientific literacy through teaching *in and about* science

Scientific Inquiry (SI) is a key component of science and of achieving an understanding of the NoS and scientific literacy. Lederman *et al.* (2014) describe scientific inquiry as including such things as: observation; classifying; predicting; measuring; questioning; interpreting; inferring and analyzing data. These skills need to be combined with scientific knowledge, reasoning and critical thinking with argumentation and logic. Not all SI involves utilizing all these skills and the form that SI could take can be more than one, e.g. descriptive, correlational or experimental. Thus, SI can be viewed, and often is, as a set of skills rather than as a cognitive aspect of science. In delivering knowledge about scientific concepts first (figure 3.2) followed by scientific inquiry which focuses on what student can do (observe, measure, manipulate equipment etc.) cognitive aspects of scientific inquiry such as the use of evidence to make assertions, to justify or even to theorize may be downplayed or even left out. This approach is unlikely to promote an understanding of the NoS or multi-dimensional scientific literacy (Bybee, 1997). Alternatively, delivering an understanding of the NoS then SI combined with teaching the knowledge and content of scientific concepts is more likely to lead to scientific literacy, as shown in figure 3.3.

### 3.6 The scientific method and the nature of science

The consensus NoS characteristics (section 1.1) specify that ‘the scientific method’ is part of the NoS, but that it needs to be understood that there is no ‘one’ way of conducting science. There is plenty of evidence from research to show that the idea of ‘the scientific method’ is a myth rather than a reality (Benjamin, 1956; Feyerabend, 1975; Bauer, 1994; Wivagg, 2002; Tang *et al.*, 2009). Various methods are used within science, but this does not validate the use of the term ‘the scientific method’. If anything, it should be ‘the methods of science’ to reflect the fact that different science disciplines, operate different ways of investigating, experimenting and gathering evidence as well as testing of ideas. Sir Peter Medawar (1915–1987), a Nobel Prize winner in medicine, with characteristic wit, said:



Ask a scientist what he conceives the scientific method to be and he (sic) will adopt an expression that is at once solemn and shifty eyed: solemn because he (sic) feels that he (sic) ought to declare an opinion: shifty because he (sic) is wondering how to conceal the fact that he (sic) has no opinion to declare. (Medawar, 1969, p.11)

Two books robustly challenge the notion of ‘the scientific method’, Feyerabend’s (1975) *Against Method* and Bauer’s (1994) *Scientific Literacy and the Myth of the Scientific Method*.

### 3.6.1 Feyerabend’s ‘Against Method’

Paul Feyerabend (1924 – 1994) went against the prevailing thought of the day. He rejected outright the idea of a single ‘method’ for science. He challenged the notion on the basis that should a single method exist it would impede scientific progress. Science, he claimed, is an essentially ‘*anarchistic enterprise*’ (Feyerabend, 1975, p.1); progress, he argued, is more likely to be stifled by methodology than promoted. He concludes that, ‘...there is only one principle that can be defended under **all** circumstances and in all stages of human development. It is the principle **anything goes**’ (Feyerabend, 1975, p.12 Feyerabend's own emphasis).

Feyerabend’s argument continues by stating that science should proceed ‘*counter inductively*’ (Feyerabend, 1975, p.13). By this he means, rather than interpret any new data or evidence with reference to established theories, we should postulate inconsistent and different claims for the theory. This is an example of his ‘anarchic’ approach to science. It counters what he sees as the practice of scientists which produces hypotheses that agree with established theory – what he called ‘*the consistency condition*’. As he points out, ‘*no single theory ever agrees with all the known facts in its domain*’ (Feyerabend, 1975, p.17 & p.33). Feyerabend’s ideas were not accepted without severe criticism. An article in *Nature* called him ‘*the worst enemy of science*’ and likened him to ‘*the Salvador Dali of academic philosophy*’ (Theocharis and Psimopoulos, 1987, p.596).

Feyerabend exposed the practice of science and its false claim that there is a ‘method’ by which scientists abide or science is practiced. Having said that, his view of an ‘anarchistic approach’ and rejection of consensus science as simply a form of religious dogma is neither helpful to science in general, nor science education in particular. If we were to teach an anarchistic epistemology of science, we would have to accept that ‘anything goes’ in the curriculum: denial of climate change; six-day creationism; homeopathy; astrology, all become legitimate as ‘science’ and legitimate areas to explore and teach within science. Notwithstanding the lack of any positive scientific

consensus on these matters, the subject itself would in effect cease to exist as a defined set of disciplines; everything and nothing becomes science and scientific.

### **3.6.2 Bauer's myth of the scientific method**

Bauer's (1994, p.23) book sets out immediately to dismiss a common view of science saying that, '*...purportedly authoritative pronouncements as well as popular ideas about how science works are very seriously mistaken*'. Another misconception about science, claims Bauer, includes the idea of a commonality of approach between sciences. He sees the root of the problem as emanating from the nineteenth century and the growth of experimental science across many different fields. That science can be thought of as being theoretical (as in theoretical physics) or experimental (as in experimental physics) is itself a reason for doubting the existence of 'the scientific method'.

While 'the scientific method' may be a myth, it is part of the curriculum for science in many countries and it guides the way that SI is taught and practised in schools. The issue is whether or not this one aspect of teaching science is acting as a proxy for the NoS and distorting or obscuring a better understanding of the nature of science.

### **3.7 Empirical studies on the nature of science**

A number of studies on science teachers' conception and understanding of the NoS have been conducted since the mid-1980s (Lederman and Zeidler, 1987; Bloom, 1989; Brickhouse, 1990; Hodson, 1993; Blanco and Niaz, 1997; Mellado, 1997; Palmquist and Finley, 1997; Tobin and McRobbie, 1997; Lederman *et al.*, 1998; Lederman, 1999; Abd-El-Khalick and Lederman, 2000; Bell *et al.*, 2000; Tairab, 2001; Backhus and Thompson, 2006; Southerland *et al.*, 2006; Ozgelen and Tuzun, 2012; Abd-El-Khalick, 2013; Ozgelen *et al.*, 2013; Mihaladiz and Dogan, 2014). The results of these studies indicate that no apparent link between teachers' conceptions of the NoS and their teaching behaviour exists. Researchers used a variety of instruments to assess teachers' understanding of the NoS. The nature of the instruments changed in the 1990s from fixed multiple choice type questionnaires to open-ended instruments. These newer instruments, often known as VNOS questionnaires (Views on the Nature of Science questionnaires), elicit views from interviewees on a range of questions related to the common aspects of the NoS as set out in section 1.4. Prior to this, various standardised instruments were used to ascertain teachers understanding of the NoS. These had various problems, for example, validity and were only capable of producing crude labels of 'adequate' or 'inadequate' views on the NoS.

It is interesting also to note that in one of the more recent studies, utilising an open-ended questionnaire and interviews (Bell *et al.*, 2000), pre-service high school teachers had an

understanding and conception of the NoS that was consistent with contemporary ideas of the NoS. They saw it as an important teaching goal in science education, though none of them thought that they had addressed the NoS adequately during their own teaching. They cited several constraints to explain this. In general, they perceived there to be a conflict between teaching the NoS and teaching the science content and process skills. This is an important finding. It illustrates the tensions in trying to deliver the NoS when the curriculum prioritises knowledge of scientific concepts and the practical skills of science over a coherent view of the sciences; the commonalities and differences between scientific disciplines and an epistemological understanding of science.

Another constraint identified in Bell's study was the substantial amount of time required to teach the NoS, which would cause teachers to fall behind other teachers, not delivering the NoS in the content coverage. Hodson (1993) had reported similar findings in his study conducted with primary school science teachers. He found that even those teachers who hold clear and consistent views about the NoS do not plan activities consistently in relation to those views. Instead, the teachers were more concerned with issues of classroom management and course content coverage.

There is evidence that some teachers have beliefs about the NoS that may influence their classroom practice. Brickhouse (1990), in her study with American pre-college science teachers, found that their views of the nature of scientific theories, scientific processes, and scientific progress were all correlated with their views of teaching and with their teaching actions. Some of the teachers considered scientific progress as a process that occurs through '*...the accumulation of facts rather than by changes in theory. Similarly, they expected their students to learn by accumulating bits of information*' (Brickhouse, 1990, p.57). Others believed that science progress occurs through new interpretations of old observation. Students learn science through the interplay between thinking about old information and assimilating new information. Brickhouse concluded that these teachers' teaching strategies were well aligned with their views about the NoS. This was a limited study involving three science teachers, one a beginning teacher whose views were not aligned with his beliefs. Brickhouse (1990) took a case study approach with purposive sampling, in much the same way that this case study used purposive sampling of science teachers to study a cultural domain (school-based science teaching) with knowledgeable experts in science teaching. Previous studies, by the various other researchers, for example (Zeidler and Lederman, 1989; Lederman, 1999; Liu and Lederman, 2007a), which involved much larger numbers of interviewees over long periods of time are more reliable as they are methodologically sound and different researchers have come to similar conclusions. Brickhouse's (1990)

work does raise some interesting points that are relevant to this case study, such as the constraints acting on teachers in schools, which may prevent them from incorporating their understanding of the NoS in teaching.

In considering this case study research, it is natural to seek out other, similar research that has been done either in the same way i.e. as a case study or using other methodological approaches. Case studies exist of interventions in ITT where courses on the NoS are delivered to trainee (pre-service) teachers (Aguirre *et al.*, 1990; Lee, 2008; Karakas, 2009; Hacieminoglu, 2014). That said specific case studies on how the NoS is integrated into the curriculum or how it develops and evolves within a curriculum over time in a country are seemingly absent. It is natural to concentrate in the first instance on work about how teachers' conceptions affect how they deliver aspects of the NoS in the classroom, e.g. Bell *et al.* (2000) described earlier. The studies indicate that the curriculum being delivered did not cover the NoS as a key teaching objective and neither did it set out to assess children's understanding.

Duschl and Wright (1989) conducted an interesting ethnographic study on the decision-making process of teachers with respect to the science curriculum. This included aspects of the NoS. They concluded that the decisions teachers make over what to include in their teaching plans rested on three main factors; children's development, curriculum objectives and pressures of accountability. Once more this does not tackle the issue of how the NoS is included or why, but it does provide interesting reasons for why the NoS and its place in the curriculum is so vital. If there are no clear objectives, no assessment pressure and the accountability measures are focussed on grades, which will be achieved mainly from knowledge of the subject matter rather than the NoS, then teachers will not deliver the NoS.

Osborne *et al.* (2003) conducted a Delphi Study of 'expert panels' to determine what should be taught 'about' science rather than what content of science should be taught. In this study three rounds of questionnaires were completed by the panel experts with a view to summarising the outcomes after each round and eventually arriving at a 'consensus' opinion that could be considered as 'correct'. The study concluded that *'teaching aspects of ideas about science explicitly is possible and desirable.'* (Osborne *et al.*, 2003, p.30).

Monk and Osborne (2006) looked specifically at the history and philosophy of science and the difficulties in including this within the curriculum. They concluded that despite projects that produced good teaching materials, the history and philosophy of science *'...will remain more talked about than taught'* (Monk and Osborne, 2006, p.112).

The lack of systematic studies of the inclusion and development of the NoS within statutory curricula makes this case study potentially important and worthwhile. By examining how the NoS was included, how it was changed and developed or even significantly reduced, evidence can be gathered on what model of science education is being presented and how that relates to the development of scientific literacy.

### **3.8 Taber's curriculum model for the nature of science**

Taber (2008) proposes that there is a need for a curricular model of the NoS that should guide science teaching. In the same way that we generate models for the teaching of concepts – that is simplifications of complex ideas which enable learners to develop their understanding, so too should we have such a simplification for the NoS. An understanding of the NoS would allow children to see a more post-positivist, rather than logical positivist, view of the way in which science derives explanations for natural phenomena.

No matter how we present scientific knowledge in the classroom it will, according to Taber (2008, p.186), undergo some form of transformation either through simplification or an *'unintended "degradation" and distortion of meanings'*. He continues, saying that *'effective science teaching is not a process of transferring knowledge'*. Despite this, the structure of the SNC was, from the outset, an atomistic approach to the teaching of scientific facts and concepts without a truly integrated or understood epistemological underpinning. As Taber notes, the political dictation of the curriculum structure and mode of assessment led to a curriculum taught for accountability rather than educational reasons.

Science teachers, who to this point were used to delivering science in a logical positivist way, were unlikely to deliver the content much differently. Teachers will deliver the content according to their own conceptual understanding and mental model (Taber, 2008; 2014; 2017). Taber (2008) concludes that despite the best intentions of curriculum designers to place the NoS within the SNC, it did not lead to explicit or effective classroom teaching. Teachers regarded the NoS as a 'bolt-on' aspect of the curriculum, something that was indeed the case when I taught the curriculum at that time. The reason for this comes as no surprise. There was/is a lack of expertise among science teachers about the NoS. Taber's solution to this issue is threefold. The development of an explicit curriculum model (or models); a programme of research to explore effective teaching of such models; and revised models based on the research outcomes. In developing such models, scholarship from a variety of sources is needed e.g. logic, argumentation, philosophy and history of science.

In a later paper, Taber (2017) once more challenges a positivist view of science and promotes teaching *about* science rather than *in* science. Presenting science as a series of facts or concepts that are representative of the real world to be ‘believed’ he claims does not present an accurate view of the nature of scientific knowledge. This is a viewpoint with which I fully agree. Science is not a belief system; rather it is about the acceptance of evidence (Williams, 2009; 2013; 2016).

### **3.9 Teacher knowledge and the place of the nature of science**

If the NoS is to be taught effectively, teachers must have knowledge of it. The knowledge needs also to be explored from a pedagogical perspective. Knowledge itself can be seen from three different perspectives, tacit, explicit and implicit knowledge.

Tacit knowledge was summed up by Polanyi (2009, p.4) as, ‘*we can know more than we can tell*’, it is the sort of knowledge that we have, but cannot easily explain why we have it or how we came to know it. Explicit knowledge on the other hand is that knowledge which is expressed in writing, e.g. in journal papers, textbooks etc. As Smith (2001, p.315) describes it: ‘*Explicit knowledge is technical and requires a level of academic knowledge or understanding that is gained through formal education, or structured study*’.

The third form, implicit knowledge, is sometimes found in the literature i.e. knowledge that could be made explicit but tends to exist in more of a tacit form. There is doubt over the status of implicit knowledge, with some authors (e.g. Reber, 1989; Dalkir, 2013) using the term interchangeably with tacit knowledge. Others see implicit knowledge as just another form of tacit knowledge (Smith, 2001; Davies, 2015). For the purposes of this thesis, only tacit and explicit knowledge will be used. Implicit knowledge is given to be subsumed into tacit knowledge. Implicit knowledge may represent a stage in the journey from tacit to explicit but as this implicit knowledge is, in my view, something that is transitioning from one to the other it would have different characteristics in different people.

As noted earlier, an objective of science is to generate scientific knowledge. Scientific knowledge is knowledge derived from evidence. The knowledge is most often an inference to the best explanation, that is, it is mostly abductive in nature. Over time, our knowledge increases. Arguably, this leads to scientific progress. An interesting question is whether the continual accumulation of scientific knowledge is scientific progress? Bird (2010) summarises arguments against this simplistic notion well, using work from two influential post-positivist philosophers of science. He shows that Karl Popper (1902 – 1994) rejected this notion as no scientific knowledge could be seen as ‘true’. Kuhn

(1996), on the other hand, saw progress as a way of finding solutions to problems. Bird concludes by defining scientific progress as '*knowledge which does have the right justifying connection to the truth, typically through reliable reasoning and good evidence*' (Bird, 2010, pp.3-4). Whatever the case, teachers of the sciences are likely to require explicit knowledge, not just of the science but also of scientific progress over time in order to teach key aspects of the NoS. If their knowledge is tacit (implicit), then their ability to impart to children a good understanding of the NoS could be severely hindered.

### **3.10 Teacher subject knowledge and pedagogical content knowledge**

Subject knowledge for teaching is, understandably, important. What a teacher knows about a subject, but more importantly how they deliver that knowledge, has been the topic of much interesting research. A key figure in the research into teachers' subject knowledge, and how that translates into subject knowledge for teaching, is Lee Shulman who headed a project looking at knowledge growth in teaching. Through intensive case studies of secondary teachers, Shulman and his researchers traced the changes in teachers' subject matter knowledge as they completed teacher education and began teaching full time. Shulman (1986) described the combination of subject content knowledge and pedagogical knowledge and how it results in what he terms pedagogical content knowledge (PCK). Teachers who have good PCK are more expert than those who do not. It is the combination of pedagogical knowledge, the knowledge of how to teach and how to provide for effective learning and good subject knowledge, which includes factual knowledge, as well as an understanding of the history and philosophy of the discipline.

An understanding of subject knowledge will influence the way teachers develop and deliver the science curriculum, alongside other factors, such as the need to deliver the statutory elements of the curriculum and any public examination specifications. It is the understanding of the history and philosophy of the discipline of science that seems to be lacking. In a trial survey of trainee teachers investigated by me prior to starting this research (Williams, 2008a; 2008b; 2013), the history and philosophy of science was found to be lacking, as was a good understanding of other key aspects of the NoS and the language of science. PCK is often described as being composed of four different components:

- 1) The teacher's purpose in teaching the specified subject matter to the pupils;
- 2) knowledge of the pupils and their conceptions and alternative conceptions about the specific topics being taught;
- 3) curriculum knowledge, i.e. knowledge of the scope of the curriculum to be taught, the resources that are available for teaching;
- 4) the pedagogical strategies best suited to the subject matter.

What teachers know and understand will eventually form part of their worldview, in this instance their beliefs about a scientific worldview. While this research is not about worldviews, it is useful to examine briefly teachers' beliefs, with a view to later understanding something of their beliefs on the NoS.

### 3.11 Teachers' beliefs

Ascertaining teachers' beliefs is inherently difficult. The main problem is how to access beliefs directly and independently and, indeed, defining what a belief is or what constitutes a belief. As Pajares (1992, p.309) states:

Defining beliefs is at best a game of player's choice. They travel in disguise and often under alias—attitudes, values, judgments, axioms, opinions, ideology, perceptions, conceptions, conceptual systems, preconceptions, dispositions, implicit theories, explicit theories, personal theories, internal mental processes, action strategies, rules of practice, practical principles, perspectives, repertoires of understanding, and social strategy, to name but a few that can be found in the literature.

Kagan (1992, p.66), looking explicitly at research on teachers' beliefs and how these may impact on teaching, notes that '*...teachers are often unaware of their own beliefs, they do not always possess language with which to describe and label their beliefs, and they may be reluctant to espouse them publicly*'.

Beliefs are often cited as being involuntary dispositions (Cohen, 1992) and different from the acceptance of a situation. Consequently, a science teacher may **accept** the need to teach the science curriculum and, with it, accept its way of defining such things as the NoS, 'scientific method' or scientific literacy, but may, in contrast, **believe** that these definitions are deficient, incorrect, etc. This poses a problem when developing good subject knowledge, which can later be developed into good PCK.

### 3.12 Defining and theorising 'the curriculum'

The development of any curriculum deserves study. Ideally through the lens of a theoretical approach. That said, 'Curriculum Theory', as a way of examining and explaining the curriculum, has no simple interpretation or definition that is universally agreed. Pinar (2011, p.11), for example, describes 'Curriculum Theory' as '*the scholarly effort to understand the curriculum*' which he conceives of as '*a complicated conversation*'. Others prefer to remove the term 'theory' and instead discuss 'Curriculum Studies', for example, Kelly says:



Curriculum studies cannot be seen as a science. The history of attempts to theorize about education is littered with examples of this kind of scientist approach, and all of them have been theoretically misleading and practically harmful. (Kelly, 2009, p.25)

Priestley (2011) notes, however, the concept of 'theorising' the curriculum was popular in British educational circles during the 1970s and 80s, leading to a range of theoretical models such as Hirst's knowledge-based model, Lawton's sociological cultural invariants model and the school-based, process models advocated by Stenhouse and Kelly (Priestley, 2011).

Another issue is how we define 'curriculum'. It may be as broad a definition as the NC, such as the one we have in place in England. This not only encompasses various subjects, but also a wide range of ages. It is the totality of subjects delivered across compulsory schooling, from the foundation stage to Post 16 teaching and learning. Or, as Kelly defines 'curriculum', it relates not to the subjects *per se*, but to the individual child where the curriculum represents the totality of the experiences the child has as a result of the provision made for their education (Kelly, 2009, p.13). The experiences a child has will arise from the subjects they are taught, but the emphasis on the curriculum as experiences for the child rather than as the subjects delivered to the child is important.

Posner (2004) sees definitions such as those described above as being either about '*means*', '*ends*' or '*actual learning*'. Means describes how a curriculum is delivered and ends concerns the outcomes and objectives. Actual learning considers what the child or student gains from the curriculum delivered. He argues that such distinctions are by no means clear-cut. Means, he states, may well be dependent on ends and ends will only be fully understood once the teaching has taken place. The ends may also differ from student to student as their learning experiences may differ even within the same classroom. Rather than try to create a simple definition for 'curriculum' – something he conceives of as '*no simple matter*' (Posner, 2004, p.5) – he opts to set out seven concepts (table 3.1) that a curriculum may entail.

Table 3.1 Posner's 'concepts of curriculum'

<b>Seven Common Concepts of Curriculum</b>		
1	<i>Scope and sequence:</i>	The depiction of curriculum as a matrix of objectives assigned to successive grade levels (i.e., sequence)
2	<i>Syllabus</i>	A plan for the entire course, typically including rationale, topics resources and evaluation
3	<i>Content outline</i>	A list of topics covered organized in outline form
4	<i>Standards</i>	A list of knowledge and skills required by all students upon completion
5	<i>Textbooks</i>	Instructional materials used as the guide for classroom instruction
6	<i>Course of Study</i>	A series of courses that the student must complete
7	<i>Planned Experiences</i>	All experiences students have that are planned by the school whether academic, athletic, emotional or social

Source: Posner (2004 p.12)

The SNC in its various draft and implemented versions meet some, but not all, of Posner's seven common concepts. Concepts 1, 3, 4 and 6 are common components incorporated within the SNC. Concept 2 does not form part of the SNC as it was simply a statement of what should be taught, with no plan rationale or resources. With the development of the SNC, there was also the development of new schemes of work for KS1-3 and syllabuses (now called specifications) to match the content of the curriculum at Key Stage 4 (GCSE level), which would conform to concept 2.

Concept 5, textbooks, were not recommended within the NC and schools were (and still are) free to choose the textbooks they felt best served their students. As time progressed, certainly for Key Stage 4, there was a closer tie-up between the specifications and the textbooks, a move that is generally criticised as having the effect of narrowing the curriculum (Puttick, 2015). Even at Key Stage 3, textbooks were produced that matched the non-statutory schemes of work. Many teachers developed their own schemes of work: long term (by year) medium, term (by term) and short term (day by day), or they bought in specific textbooks with accompanying resources that had pre-planned the long, medium and short-term objectives, outcomes and activities. Together, all the various subject curriculum documents could meet Posner's 7<sup>th</sup> concept of 'planned experiences' though they are documents that specify what to teach subject wise, rather than detailed plans that would include other non-subject based aspects of a curriculum.

### 3.13 Politics and the curriculum

As this case study examines the political influences on the NC and the SNC there is a need to look briefly at what the literature says about political influence on curriculum development in the run up to the NC and beyond. Ball (1990) characterises political policy making in education as complex, irrational and unscientific, despite the claims of politicians to the contrary. Lawton described a distinct shift in how politics and politicians engaged with curriculum theory, starting with Thatcher during her tenure as Secretary of State for Education in 1970, *'the politics of the school curriculum might be seen as a shift from "partnership to accountability"'* (Lawton, 1983, p.5). This was accompanied by a necessary centralisation of education with more direct control from the government department responsible, the then DES. The chaotic nature of policy and the move to a more centrist vision (albeit with promises that, far from more central control the policies and new statutes would deliver more autonomy) are summed up by Ball's (1990, p.3) view on the 1988 ERA which he said contained *'a number of "shots in the dark", policies without pedigree.'*

Ball viewed many of the changes in the Thatcher and Major era as a form of 'cultural restorationism'. This was an appeal to parents and others for a return to some form of traditional education characterised by academic rigour, strict behaviour and the imposition of moral values through education. It was an appeal against progressive forms of education, which had been identified by what he called *'hard line, old humanists of the New Right'* (Ball, 1990, p.6). Many issues identified by politicians as social problems were linked to a decline in educational standards, with a seemingly concomitant rise in trendy progressive teaching methods. A return to traditional education would, it was argued by the 'new right', rectify many issues. Table 3.2 shows the key 'actors' involved in educational policy making along with their ideological positioning.

A turning point in the relationship between government, the local authorities and schools was the William Tyndale affair. William Tyndale primary school run by the Inner London Education Authority instigated a curriculum and school ethos that went beyond the progressive methods employed by many schools in the 1970s. The newly appointed headteacher instigated 'open' and 'closed' hours of teaching and free access to all areas of the school for all pupils. In the 'open' hours the children were free to choose any activities they wished to do, which apparently included the ability to walk out of school. The school did not have a parent teacher association (PTA) for fear that it was dominated by middle-class parents who would seek to control what the school delivered and how it was delivered. Children were allowed to leave the site, simply roaming the streets and there were reports of gambling (using their dinner money) and an unsafe environment

with bullying and other anti-social acts (Davis, 2002). This led to a breakdown in relationships between teachers, the school management, the Local Authority and involved questions being asked about the responsibilities of government in ensuring education was effective. A parliamentary enquiry was critical of all the parties involved and led to calls for more centralisation and government control over Local Authorities. Central government had, until this point, been noticeably absent in the affairs of local schools. As Jackson and Gretton (1976, p.50) observe in their book on the affair, *'After William Tyndale, the Secretary of State can no longer pretend, as he and his predecessors have so often tended to do, that it is all happening somewhere else.'*

Table 3.2 Educational ideologies

	<b>Beliefs</b>	<b>Values</b>	<b>Preferences</b>
<b>Politicians</b>	Market Forces	Freedom of choice	Private schools
<b>Bureaucrats</b>	Good administration, management systems, maintenance	Efficiency	Central Control examinations/tests
<b>Professionals</b>	Professionalism, experience and practice	Quality	Impressionistic evaluation

Adapted from Lawton (1986, p.35)

Kelly (2009), sees the pre-NC period as one where politically there was a move to separate the vocational and academic aspects of education. The setting up of schemes such as the Technical and Vocational Education Initiative (TVEI) in schools, the Youth Opportunities Programme (YOP), which became the Youth Training Scheme (YTS), helped find employment for school leavers alongside the Manpower Services Commission (MSC), which had a brief to co-ordinate employment and training. This led to a separation of pupils into 'academic' and 'vocational' groups and a separation of training and education.

### 3.14 Summary

Several key themes emerge from this review of the literature. Literature was selected for its relevance, ability to question or challenge my own ideas and ideals, or open new directions of thought with respect to the NoS, science curriculum in schools and the politics of education.

Robinson (1998), emphasising the importance of the NoS within scientific literacy, recognised the need to include it within science education over fifty years ago. He also expressed difficulties in defining the NoS and a need to understand the differences between the various disciplines of science. Since that point the NoS has evolved in meaning and in how it is (or in many cases is not) a formal part of the science curriculum. In the 1990s, a more coherent view on the NoS emerged, particularly from the work of Driver *et al* (1996). This book was concerned with young people's images of science, but chapter 3 outlined the current state of play with respect to understanding the NoS and it looked at some of the implications for science education, such as supporting successful learning in science, better use of science in later life and the appreciation of science as a human endeavour.

Others, including Lederman (2007; 2013), have sought to define broadly the NoS and put forward some key characteristics that would be useful within science education e.g. the tentative nature of scientific knowledge; the empirical nature of science; that there is a difference between theories and laws, as well as the part played by interpretation, inference, creativity and imagination. There is also the fact that scientific knowledge is socially and culturally embedded.

Scientific literacy, like the NoS also suffers from a diverse range of ideas about what it is, though Bybee's (1997) model offers the most complete range of levels from scientific illiteracy to multi-dimensional scientific literacy.

Scientific Inquiry (SI) or the processes and skills involved in scientific discovery also play a part in the NoS, but can, as has been discussed, lead to a misunderstanding such that SI becomes a proxy for the NoS. Although SI involves many practical skills, such as observation, measurement, manipulation of equipment and even data, it can far too easily omit the role of logic, argumentation, creativity and critical thinking.

How science is presented, as in a positivist or logical positivist way, can lead to an assumption that taking a 'hands-on' practical, investigative approach to science will somehow deliver an understanding of the NoS and lead to scientific literacy. A problem with this approach is the evidence that teachers' conceptions and understanding of the NoS are poor. It is clear from the research over the years that embedding the NoS into classroom teaching and learning is difficult. The success rate is relatively low. It is also clear that teachers' conceptions of the NoS are similarly diverse.

Even where a teacher has a well-developed understanding of the NoS this does not translate into effective teaching or incorporation of the NoS into lesson plans. A major

constraint on this, identified in the research, is the idea of the curriculum as a tool for accountability being used to measure the effectiveness of teachers through the outcomes of their students in public tests and/or examinations. This encourages a mind-set of ‘teaching to the test’ and invariably the tests focus on content and skills over an epistemological understanding of the subject.

A further complication arises from the commonly stated, but functionally empty phrase “the scientific method” (TSM). At best this should be “the methods of science” or, better still abandoned completely. How TSM aligns and intersects with SI is also problematic as TSM can be confused with the protocols of doing and recording a scientific experiment.

How we conceive of a curriculum varies according to its perceived purpose. A curriculum could be anything from the complete education experience of a child throughout that child’s education to a planned set of lessons for delivering a single discipline within the sciences. The curriculum we have in schools should be specified in terms that make it clear if what is being presented is a curriculum of means or of ends.

Finally, the influence of politics and politicians on the curriculum cannot be underestimated. Policy, when created by politicians, far from being rational, scientific, evidenced and neutral (politically) is rarely that. From the 1970s, there was an increasing desire from politicians to move beyond the structural aspects of schools and education. Rather than opting for the status quo, which saw local accountability for schools and the curriculum under the auspices of local government, there was a move to centralise and become more involved in the curriculum and ultimately its content. Events, such as the William Tyndale affair, were a catalyst for politicians to plan for and enact policies and legislation that would eventually lead to the NC and the SNC.

## **Chapter 4**

### **The Research: Methodology, Methods and Ethics**

This chapter begins with a clear statement of the research questions and how these were developed. Next, there is a short, personal introduction to the problem of moving from one subject discipline to another; that is from a scientific (natural sciences) background as a young graduate then teacher of sciences in schools, to a social scientific discipline as a teacher educator and researcher in science education. I then examine the ontological, epistemological and axiological beliefs that form the foundation of the research.

After this, the chosen approach for the research, a case study, is examined. This is followed by a description of the methods employed, outlining why they provide the best evidence for the research. Issues surrounding withdrawal of consent by one interviewee are addressed next.

Finally, reliability, validity and generalizability alongside the strengths and weakness of the research approach taken are discussed.

#### **4.1 The research questions**

The origin of the research questions (RQ) that drive this case study comes from my own interest and developing knowledge and understanding of the NoS and the involvement of politicians in determining the curriculum in schools during my time as a science teacher in the mid-1980s. As a child studying science in school, taking an interest in science outside school and as a science undergraduate, the NoS was not a concept I was taught explicitly, knew about or understood. My experience at all levels had been of science as a body of knowledge (facts) to be 'learned'. In addition, there were skills to be learned e.g. manipulation of laboratory equipment/chemicals and how to design an experiment. TSM was, for me as a student of sciences, simply how to do an experiment and how the results of experiments should be written in a laboratory journal.

As a teacher of sciences in state schools, the NoS did not consciously feature in my lesson planning or curriculum construction. Terminology such as inductive, deductive, abductive reasoning or logic were not fully understood by me, even though I used logical thinking to explain how evidence in science leads to knowledge and understanding of concepts. Having very briefly taught the old O level and CSE syllabuses, which were not government controlled, I was part of the generation of teachers who experienced the new political involvement with the curriculum as the full national curriculum was enacted

in the late 1980s. How this influenced schools and teachers and how it created organisational issues also prompted this research.

One controversial issue in science has been a constant interest of mine for over 30 years, creationism and evolution. Having studied the life and work of Charles Darwin (1809-1882) and Alfred Russel Wallace (1823-1913), the originators of the theory of evolution by natural selection, I developed an expertise and interest in the history and development of their theory over time. Studying why creationists do not accept evolution, why creationism and intelligent design creationism is not science, I became aware of the role of the history and philosophy of science, the NoS and TSM in making determinations about what science 'is' and how science is 'done'. Creationists try to use the NoS and TSM to argue against evolution as science, in a bid to characterise it as a religious belief system. This led to my increasing desire to understand how the NoS could contribute to a better understanding of science at all levels, especially in school science. A good understanding of the NoS enables people to see why creationism is not science. It is fundamental to being scientifically literate.

This background led to an interest in the NoS and TSM in the science curriculum. As a practicing science teacher during the period being reported in the case study, I had to grapple with the NoS as a new part of the science curriculum. Over the intervening 25 years I variously taught about the SNC or developed teaching material for the SNC.

Having accumulated a wealth of knowledge and understanding about the SNC, this led ultimately to developing ideas and questions that could be researched. For this case study, I wanted to examine the various influences that affect a state mandated curriculum and how the NoS was incorporated, and subsequently evolved/developed, through various revisions of the SNC. It was clear in the late 1980s and early 1990s that politicians were leading the reforms in schools at various levels, from the structure of schools, to the removal of powers from Local Authorities and to some extent the content of the various curriculum documents. This level of political influence was unprecedented in English education. Reflecting on this raised important questions that I felt needed answering.

The initial process of deciding on suitable research questions was to generate ideas about the topic of the NoS in the curriculum, having viewed and considered a range of research papers (see Chapter 3). From this, I refined and unpacked the ideas generated to formulate researchable questions. Using Cohen *et al's* (2013, p.111) approach it enabled me to move from *'a general set of purposes to a range of specific, concrete*



*issues and areas to be addressed in the research, and, for each, to frame these in terms of one or more research questions’.*

The Main questions for this research consider the development and evolution of the NoS within the SNC

RQ 1 What was the origin of the SNC and how did it develop over time?

RQ 2 What were the political, educational and organisational influences on its origin and development?

Supporting these key questions are other more specific questions that inform the subject of the research and drive the case study.

RQ 3 How has the NoS been incorporated into the science National Curriculum?

RQ 4 How is the NoS articulated in the science National Curriculum and does this vision of the NoS promote coherence across the sciences?

RQ 5 How has the evolution and development of the science National Curriculum affected the NoS and its incorporation into science education?

RQ 6 How does the incorporation (or lack) of the NoS affect how different scientific disciplines are viewed by science teachers?

The rationale for asking these research questions is to gain a better understanding of the curriculum through time. Although the questions as stated are mainly ‘how’ questions, key aspects of these questions include an understanding of the ‘Who?’, ‘When?’, ‘Where?’, ‘What’, ‘Why?’ questions, for example, who created the curriculum? Why was a NC needed? Ultimately, the answers to these questions, generated from the case study, will lead to a better understanding of what influences and tensions there were on the science curriculum and how these affected the coherence of that curriculum.

## **4.2 The research questions explained**

### **4.2.1 RQ 1 What was the origin of the SNC and how did it develop over time?**

This question seeks to understand why the NC and, specifically the SNC, came into being and how it evolved over time. The school curriculum had developed in an organic way since the start of state provision of schooling (Jenkins, 2019) and, prior to that, various science curriculums were developed by various private (independent) schools (Brock, 1977). Once the state mandated that children must attend school, e.g. as a result

of the 1870 Forster act (Forster, 1870), schools had to provide a curriculum. The first formal curriculum, listing subjects to be taught, was introduced in 1904 (Lowe, 1984) but the specific content of the curriculum was decided by the exam board syllabuses and individual schools/teachers.

This question explores the origin of the NC, how it came to be in place and how it evolved over time. To answer this question various documents including HMI reports, government commissioned reports on the state of the school curriculum as well as the acts of parliament that laid the foundations for and the legislation required to bring a NC into force will be examined and analysed. The SNC documents that were proposed and in force will then be used to look at how the curriculum for science, and in particular a key aspect of the curriculum, the NoS, evolved over time. There are various ways in which such a curriculum could develop. For example, a slow gradual process where curriculum content changes, or changes to structure, would be minor and over time move away from the initial structure/content, or in a more dramatic way, where major changes could be effected in a short timescale, while keeping the main structures intact or, at the other extreme in a stochastic way.

#### **4.2.2 RQ 2 What were the political, educational and organisational influences on its origin and development?**

Following on from RQ 1, this question further examines the political, educational and organisational influences on the origin and development of the SNC. The reports education acts and documents examined in RQ 1 will be set alongside the accounts of the politicians responsible (extracted from their autobiographies and biographies) for enacting the NC, to ascertain the political motivations for a NC and a SNC. The main aim of this question is to understand the key drivers for the introduction of a NC. Was this purely for educational purposes, only to deliver to children a rounded broad based education, with no other purpose than self-development and the development of intellectual (and scientific) curiosity? Or, were there other drivers, such as the need to hold schools and teachers to account, or to ensure a plentiful supply of suitably educated people to meet the demands of our economic and industrial plans and ensure the UK's place as a world leading industrial and economic force. The question also addresses the issues of organisation within schools, e.g. is the development of separate curriculum content practical? Within science the curriculum started as a series of 'big ideas' in science. It was quickly reduced back to the original notional three sciences of biology, chemistry and physics, yet there was a squeezing of five separate disciplines (biology, chemistry, physics, geology and astronomy) into three subjects. This will be examined

by looking at how the curriculum content was changed and re-arranged in the various versions of the curriculum over time.

#### **4.2.3 RQs 3 – 6 The place of the NoS in the curriculum**

The remaining research questions specifically address the place of the NoS within the curriculum. RQ 3 determines what the NoS is according to the various SNC documents and compares this with a general conception of the NoS.

RQ4 looks at the problem of coherence in the curriculum – how the NoS could address coherence and whether or not the various versions of the curriculum support coherence or undermine coherence. There is an assumption that ‘science’ is just science. While it is recognised that there are different disciplines of science (as stated above), these may not necessarily operate in the same way. For example, how a physicist investigates forces and the methods a theoretical physicist uses to determine say the nature of gravity, will not be the same approach as taken by a biologist who is seeking to develop a theory about how life developed and diversified. Does our curriculum enable learners in science to understand the various approaches and methods scientists use to determine answers to their questions? To answer this question, the SNC versions will be analysed along with interviews of science teachers who were taught science as children when the SNC was in force and who have since gone on to train in science (through gaining science degrees and for some, working as professional scientists).

RQ 5 looks at how the NoS has been changed/affected during the various revisions of the SNC and examines its placement (e.g. as a full AT or as part of the PoS).

Finally, RQ 6 again utilises the results of the semi-structured interviews in order to ascertain whether having the NoS as part of the SNC leads to a better understanding of the NoS. This is a difficult question to answer from document analysis. The fact that there are only a few teachers interviewed means that the results will be impressionistic only. It may well be the case that other influences (e.g., whether or not they studied any history and philosophy of science etc. as part of their science degree) complicate the outcome. Nevertheless, it will be interesting to see if the small sample interviewed have differences or gaps in their understanding of the NoS, similar to those found in previous research with pre-service and serving teachers (Irez, 2006; Aslan and Tasar, 2013; Ozgelen *et al.*, 2013; Sumranwanich and Yuenyong, 2014).

#### **4.2.4 The meaning of ‘political’, ‘organisational’ and educational’ within this case study**

This case study examines the political, organisational and educational influences on the development of the NC and, in particular, the SNC. How these terms are defined and used is explained briefly below.

**Political influence:** Politicians have influence over many aspects of our lives and over society in general. This is no different in education. Politicians will have ideological stances (e.g. for or against private education, selection etc.) as well as political objectives, such as holding schools/teachers to account. This case study examines what political influences there were on the setting up and introduction of the NC and SNC, in part through the biographies and autobiographies of those politicians involved in setting up and enacting the SNC.

**Organisational influence:** A centrally defined curriculum will pose organisational opportunities and problems for schools and teachers. In this case study, how the curriculum influenced how science was taught (e.g. as discrete disciplines/subjects or as ‘big idea’ concepts and topics) will depend on how schools organised the delivery in the timetable and how the teachers were allocated (e.g. as teachers of separate sciences or as multidisciplinary teachers delivering two or three sciences to their classes). While this case study will not look at the timetables of schools, the teacher interviews will look at how it was taught by asking questions around memories of science in primary and secondary school.

**Educational influence:** The case study traces the educational influence over the science curriculum from its earliest days through the nineteenth century as well as how universities specified the content of science required for public examinations for entry to higher education. Within this, we also encounter the ideas of science literacy and scientific literacy and the role of the NoS in determining if a curriculum leads to the former or the latter. There is also an account of how the teaching of science was influenced by key curriculum initiatives, such as Nuffield Science or SATIS (SATIS, 1986; Anon, 2018b).

#### **4.3 A scientist in social science: journeying to a theoretical position**

I want to understand the world from your point of view. I want to know what you know in the way you know it. I want to understand the meaning of your experience, to walk in your shoes, to feel things as you feel them, to explain things as you explain them. Will you become my teacher and help me understand? (Spradley, 1979, p.34)

The quotation above reflects the main difficulty I had with qualitative research. For a natural scientist, the subject of research is often an object or a natural phenomenon, perhaps a problem, where interaction is either not possible, or is likely to influence the result such that the outcome of the research itself is invalid, or at least unreliable.

Being part of the research is anathema to some scientists who, like me, have been brought up to believe that research is conducted from the outside, looking in. Even in writing up natural science research, you are encouraged to purposely exclude writing in the first person as a sign of the author's 'objectivity'. As Ziman (1996, p.751) noted:

The idea that academic scientists have to be 'disinterested' means that in presenting their work publicly they must discount any material interests that might prejudice their findings and adopt a humble, neutral, impersonal stance that hides their natural enthusiasm for their own ideas.

Coming to terms with the need to acknowledge my part in this research and how I can generate meaningful results has been one of the most difficult aspects of the process. At all points, when: interacting with people in a researcher/interviewee relationship; gathering and interpreting interview data; evaluating science education policy; analysing the curriculum; I needed to keep in mind that the research had an emic approach, whilst also striving to be etic in part to enable me to be objective, and as unbiased as possible.

#### **4.4 My research paradigm: post-positivist, critical realism**

That there exists a natural world and a social world is fundamental to my thinking. Philosophically they may exist independently, but in seeking to understand the NoS, they cannot exist independently. We cannot determine the NoS without reference to the natural world. That said, the natural world will still exist without the social world.

In seeking to examine these two fundamentally different, yet in my view interrelated domains, I was aware of the need to have a research paradigm that satisfies the 'scientist' in me and the need to recognise that science and a scientific approach would not reveal the fundamental understandings that people have of science – their social constructs. These constructs of science may be shaped by scientific protocols and methods, but beneath that, biases and different interpretations would ultimately shape their views. Positivism is deeply embedded in the history of science and within mathematics. It is a view that whatever exists can be verified through experiments, observation, and mathematical or logical proof.

#### 4.5 Post-positivism

Post-positivism has its origins in positivism (Cohen *et al.*, 2013). In basic terms, positivism holds that we can only know what we can observe and what we can scientifically verify. Post-positivism states that the application of logic should be used to verify what we know (Burbules and Linn, 1991). In addition, it states that, unlike positivism, it is not a search for truth or a method that can ultimately explain everything (Burbules and Linn, 1991; Sankey, 2016).

#### 4.6 Criticisms of post-positivism

The post-positivist movement is not without its critics. One criticism is based on the idea that the application of a 'scientific method' to research a complex dimension such as society (or how to design and develop a curriculum for schools, let alone teaching and learning in schools) is not possible. Science seeks to define the causes of natural phenomena. Human activity is so complex finding a cause for something is unrealistic, given that humans construct their own meaning for their own realities (Mack, 2010).

A related criticism concerns the concept of 'reality'. It could be argued, and has been by those who adhere to social constructionism, that reality is actually a social construct and that there are as many 'realities' as people – we all have a perceived reality which may or may not coincide with the perceived reality of others (Berger and Luckmann, 1966).

#### 4.7 Critical realism

Ram Roy Bhaskar (1944–2014) is considered the founder of the critical realism movement. Bhaskar was working towards a new philosophy of science that recognised and accommodated, but did not reject, what he felt were '*superficial and non-theoretical*' ways of researching reality (Alvesson and Skoldberg, 2009, p.39). Scott (2005) offers two propositions for the use of critical realism in educational research. His first is that using empirical research methods requires the use of meta-theory. His second is that believing that there is an independent reality does not require that we must accept how that reality operates, or is something we can know in full.

I am drawn to the position in that I believe in an independent reality, but also accept that a full explanation or knowledge of that reality is unlikely, due to the complexity of the world (universe) and the complex nature of human thought. What is necessary however, is a framework, or, as Scott (2005) refers to it, a 'meta-theory', that allows for the investigation of the assumed reality. Alvesson and Skoldberg (2009, p.40) set out the essence of critical realism:

It is the interest in mechanisms of a 'deeper dimension', which distinguishes critical realism from other traditions. It shares the interest of positivism in the objective world, patterns, generalization, and in finding causalities, but it also diverges from this tradition in claiming that the study of the observable is too superficial, as it disregards the unobservable mechanisms that produce the phenomena that positivists seek to measure and explain. It is not possible to reduce the world to observable objects and facts, critical realists argue. Moreover, they do not accept a distinction between theory and observation, nor the interest in finding all-encompassing laws. Instead critical realism takes an interest in complex networks of theoretical and observable elements characterizing efforts going beyond the surface of social phenomena. It shares with a great number of qualitative approaches an interest in synthesis and context, but it also strongly emphasizes the objective nature of reality, and it argues that a focus on social constructions is insufficient and misleading.

This description convinced me that this approach, bringing together the scientific and social scientific worlds, would suit my own beliefs and worldview. This approach acknowledges that social constructions of reality exist, but it tends to place these constructions not at the heart of any explanation but limits their role in explanations of reality.

#### **4.8 Criticisms of critical realism**

One of the main objections to Bhaskar's critical realism is the abstract nature of his conception of social structures and the fact that it makes ontological assumptions. As Magill (1994, p.121) says, '*It is true that thinking about society involves ontological assumptions, and doubtless also that mistaken ontological assumptions can be damaging to investigation.*' Another criticism is the dismissal by critical realists of the use of statistical analysis (Steele, 2005).

Despite the criticisms and objections to post-positivism and critical realism, I still favour this paradigm over others as a frame for this research. Some of the objections and problems raised are specific to other social science domains e.g. Steele's (2005) lack of statistics which, in economic research, would be an issue. The ontological assumptions are also not ones that make any grand claims. As such, the ontological assumption that the study of the natural world is real and that there is a NoS, which informs the boundaries of that study, should not be an assumption that would damage the integrity of this research.

#### **4.9 My ontological perspective**

The relationship between ontology, epistemology and axiology will influence a researcher's methodological approach and the methods used in gathering data. As Scott (2005, p.634) says:

Critical realism makes the assumption that an ontological theory presupposes an epistemological theory; and further to that this meta-theory influences the way data are collected and analysed about the social world (the strategic and methodological levels).

Ontology, or the philosophical study of what exists and, ultimately, what that means (Craig, 2005), is the initial framing point for this thesis. I accede to the view that nature exists; natural science is the study of the natural world and universe. I believe also, that independent of our thoughts there is a reality. Within this, I also acknowledge that there is a 'Nature of Science', which describes the boundaries of what is and what is not natural science.

I also accept that views on the NoS may not be internally consistent, as different people will construct their own view of the NoS differently. In the same way that I believe no 'one' scientific method exists, there is no 'one' NoS (as explored in Chapter 3). There is also a lack of internal consistency within the disciplines of the various sciences, which, in my view, could lead to a lack of coherence within the science curriculum.

This thesis explores this lack of internal consistency by examining how the NoS is presented through policy, the curriculum, and other documents, and the views of some science teachers.

#### **4.10 My epistemological perspective**

Epistemology is a study of the nature, sources and limits of knowledge (Klein, 2005). I hold a naturalistic epistemological position rather than a normative one. The normative position is that, where we have a belief we should judge the reasons for our beliefs and, if those reasons are sound (logical), we may consider our beliefs to be 'knowledge'. The naturalistic position holds that, what we need to understand are the conditions under which beliefs can be considered as 'true'. There is an application of scientific 'methods' in judging the conditions under which a belief may be held to be true. Once it has been established that the beliefs and conditions are true, only then can we define the beliefs as knowledge (Klein, 2005). In other words, it is not enough to simply reason that a belief that is held is true and *ipso facto* it becomes knowledge. There must be a reliable source, which is subject to scientific scrutiny, to consider that a belief is true. Only then can we consider this belief to be knowledge.

#### **4.11 My axiological perspective**

Axiology, or value theory as it is sometimes known, considers the nature of value and what things have value (Lemos, 1999). Examples of value in this sense would be aesthetic (beauty) or moral (right or wrong). Value can also mean simply that something



is 'of interest'. My position here is that the way in which the NoS is understood is valuable – it is valuable because it is of interest to me and, judging by the research undertaken on it across the world, it is of interest to many others.

Another aspect of axiology is the way in which the research is conducted; is it value-free or value-laden? The role of axiology within a research paradigm is important. In strict positivism, for example, the research should be done in a value-free way, with scientific objectivity and the researcher looking in from the outside. In social science research, the values of the researcher can influence how data are interpreted. There would be an acknowledged bias that the researcher is influenced by their own worldview, experiences etc. If the researcher is part of what is being researched and cannot easily be separated, the outcome will be more subjective than objective. In this respect my own experiences, worldview and cultural upbringing will contribute to my thinking. Acknowledging this does not mean that objectivity cannot be brought to bear. It is important therefore to have explored these values to know if, or when, they may impact on the research being undertaken. It is also important to understand my axiological position to 'control' for this in any analysis and interpretation.

Having looked at, explored and understood my own ontological, epistemological and axiological positions in the search for a suitable research paradigm, I now had criteria that helped eliminate paradigms that conflicted with my beliefs. As Cohen *et al* (2007, p.1) recount:

Hitchcock and Hughes (1995: 21) ... suggest that ontological assumptions give rise to epistemological assumptions; these in turn give rise to methodological assumptions; and these, in turn, give rise to issues of instrumentation and data collection.

Determining my beliefs determined my selection of an appropriate research paradigm. This in turn helped me understand the issues that surround the determination of my methodology, methods, data collection and analysis.

#### **4.12 My methodological approach and research design**

Social Science research deals with reality differently from science. As Flick (2009, p.19) states:

Qualitative research becomes a continuous process of constructing versions of reality. The version people present in an interview does not necessarily correspond to the version they would have formulated at the moment when they reported the event happened. It does not necessarily correspond to the version they would have given to a different researcher with a different research question.

Producing a thesis that describes the ‘reality’ of how a SNC was conceived, constructed and delivered may be desirable, but realistically it is impractical as Flick indicates. Having reviewed research methods literature and looked at various methodologies, it was clear that a case study would be the most appropriate methodology to adopt.

Cohen (2013, p.290) provides ‘hallmarks’ that apply to a good case study, these provide a basis for this research:

1. it is concerned with a rich and vivid description of events relevant to the case;
2. it provides a chronological narrative of events relevant to the case;
3. it blends a description of events with the analysis of them;
4. it focuses on individual actors or groups of actors and seeks to understand their perceptions of events.

Cohen also warns that there is a degree of caution needed when reporting a case study to avoid distortion. This embraces not reporting only stand out features within the case, not being selective with evidence (so avoiding bias, which can lead to misrepresenting the whole case), avoiding giving anecdotal accounts undue weight, accepting unquestioningly respondents’ views or excluding contradictory accounts.

What is under study is a ‘case’, so it is important to define exactly what is meant by this. Stake (1995, p.2) defines cases as ‘...*specific, complex, functioning things...a “bounded system”...*’. Yin (2013, p.16), however, defines a case as ‘*a contemporary phenomenon*’, though he does also discuss defining the boundaries of a case so that it is possible to see which data are relevant to the case and which are not. In this research, two key boundaries are that it involves the science curriculum and the time period runs from 1988 to 2010.

#### **4.13 My case study research design**

In selecting a case study approach for this thesis, it was important to realise that a case study is not a method in itself. It requires the use of various methods to allow the researcher to look at ‘something’ – the case – in depth. Swanborn (2010) distinguishes between extensive and intensive research. Case study research is, by its nature, an intensive approach. It seeks depth rather than breadth and generalizability is not one of the key outcomes from the research.

Stake (1995) distinguishes between three main types of case study, intrinsic, instrumental and collective. His idea is not to categorise case studies as such, but to point to the fact that the methods used to complete the case study will differ. Intrinsic case studies, in Stake’s terms, are done from the researcher’s intrinsic interest in the

subject, or case, under study. Instrumental case studies are carried out to gain insight and collective refers to several case studies designed to form an overall understanding of something. This contrasts with Thomas (2016, pp.12-14), who describes the properties of a case study in three ways, as a '*container*', '*situation*' or '*event*' then, ultimately, as an '*argument*'.

This case study, which is the basis of this thesis, is analogous to Thomas's (2016, p.13) description of case as an '*event*' or '*situation*'. Key questions that Thomas poses are pertinent to this thesis and the description of this case. '*Where did it happen? When? What had happened before? Who was around? What was in the news?*'

Now it is worth looking in more detail at 'what' the case itself is and then review the methods used to investigate the case in depth.

#### **4.14 Defining the 'case' in this thesis**

Simons (2009, p.21) describes a case study as '*...an in-depth exploration from multiple perspectives of the complexity and uniqueness of a particular project, policy, institution, programme or system in a 'real life' context*'. In this thesis, I am looking at the development of the SNC from its inception to 2010. As such, this is an exploration, in Simons' terms, of a policy leading to a project. The policy resulted in the 1988 ERA and the 'project' was the development for the first time of a NC that specified the subjects and the content of those subjects that must be taught in state schools.

Two aspects of case study research are complexity and specificity and how these affect the case you are studying. To state that this case study is about the evolution of the NC is not specific enough, nor is it specific enough to think of just the SNC. In reading and reviewing the literature about the introduction of the NC one 'thing', time and again, came through as being the 'thing' that I should be looking at: influence. How politics and political ideology influenced the curriculum, how educational factors influenced the curriculum and how organisational factors influenced the curriculum as it was developed and was implemented. To look at this as the 'case' across the complete array of subjects in the NC would be too complex. In each subject discipline there are likely to be different many competing influences from political ones to subject professional association influences, even the influences of individual teachers in how they enact a curriculum.

To summarise, the case I am examining is influence – political, educational and organisational, and how it affected one aspect of the SNC, the NoS. The next step was to specify the boundaries of the case study.

One boundary is the subject discipline, science. A second is how the nature of science changed over time within the curriculum – this will provide an example of how one key component of science education was ‘influenced’. A third boundary was the timeframe, from 1988–2010. It is worth noting that the boundaries themselves do not define the case but seek to set the parameters within which the case study is carried out.

#### **4.15 Sources of evidence for the case study**

This thesis has three main sources of evidence:

- 1) Documentary (the curriculum and how it has evolved over time, Government policy, statutory documents, policy papers and reports etc.).
- 2) Biographical/media (the accounts of politicians and their involvement in creating/constructing the NC alongside media accounts of the same).
- 3) The experience of being taught the SNC and the understanding of key components of the NoS as recounted in semi-structured interviews with four science teachers.

The evidence gathered required different methods of analysis to be applied to different forms of evidence. The evidence needed to be studied within the contexts in which they were written or obtained. This approach means that while I will be able to provide a description and explanation of how the curriculum has developed over time, as well as a description of the understanding of a small group of teachers, this will not necessarily reveal the ‘true’ or final explanation of why the curriculum was produced, how it was produced and how it has been enacted over time. How and why it evolved and changed is also subject to an element of fallibility and/or error. Nevertheless, gaining such an understanding from a political, educational and organisational perspective provides a form of meaning for the curriculum. Analysis of the evidence will uncover sub-themes related to the main themes that run through the thesis and reveal issues, problems and successes associated with the SNC and its development.

The evidence gathered for analysis in this thesis covers a considerable time span. For example, the documentary evidence covers a period from the inception of the NC for science in the mid-1980s to 2010. The narrative interviews are contemporary but reflect on that same period as the interviewees describe their experiences of being taught within the NC. They also provide the interviewees’ current thoughts and understanding of key aspects of the NoS and TSM. The political dimension covers a much longer period, from 1976, when the idea of a common core curriculum was first formally put forward. To ensure the case is seen in its fullest context, I examined the history of science education from the 19<sup>th</sup> Century.

Each piece of evidence will have its own distinctive context (social, educational and political) and these contexts will have a bearing on the interpretation of the evidence and the formulation of the final conclusions. As Flick (2009, p.21) reminds us:

Qualitative research is oriented towards analysing concrete cases in their temporal and local particularity and starting from people's expressions and activities in their local contexts.

What follows is a description of the methods used within the case study.

#### **4.16 Curriculum analysis**

The curriculum analysis framework developed and described by Posner (2004) is the main analytical tool used within this case study (see figure 4.1). The analyses utilise Posner's 'set one' and 'set two' of the process. Posner's 'set three', 'the 'curriculum in use', is not fully applied in this process as the aim of the analysis was to see the development of the NoS aspect over time, rather than how the NoS was/is taught in classrooms. There is also the obvious problem that the historical analysis of a curriculum cannot be seen 'in use', it would only be possible to see, in part, how it may have been interpreted by textbook and resource writers. The semi-structured interviews of interviewees taught using various versions of the SNC may reveal some insights into the curriculum in use, but as noted earlier, it would be wrong to place too much weight on these recollections and reflections. These issues led to the exclusion of Posner's set three. This aspect of the curriculum, however, would be a fruitful avenue for further, follow-up research work on the current curriculum. Posner's 'set four', his question '*what can be learned from an evaluation*', will be addressed in Chapter 10, the discussion and conclusion.

Any created curriculum will have a purpose, though whether the intended purpose, i.e. the purpose intended by those who created the curriculum, is clear to those teaching and/or those receiving it is a matter of debate. In any good curriculum analysis, the following question from Posner's set two must be asked: '*what should be the purpose and content of the curriculum?*' (Posner, 2004, p.97). Posner promotes five different approaches that relate to this question.

The first, the traditional approach, is the transmission of the cultural heritage of any subject. It is about conveying the facts, concepts, principles laws values and skills of the subject.

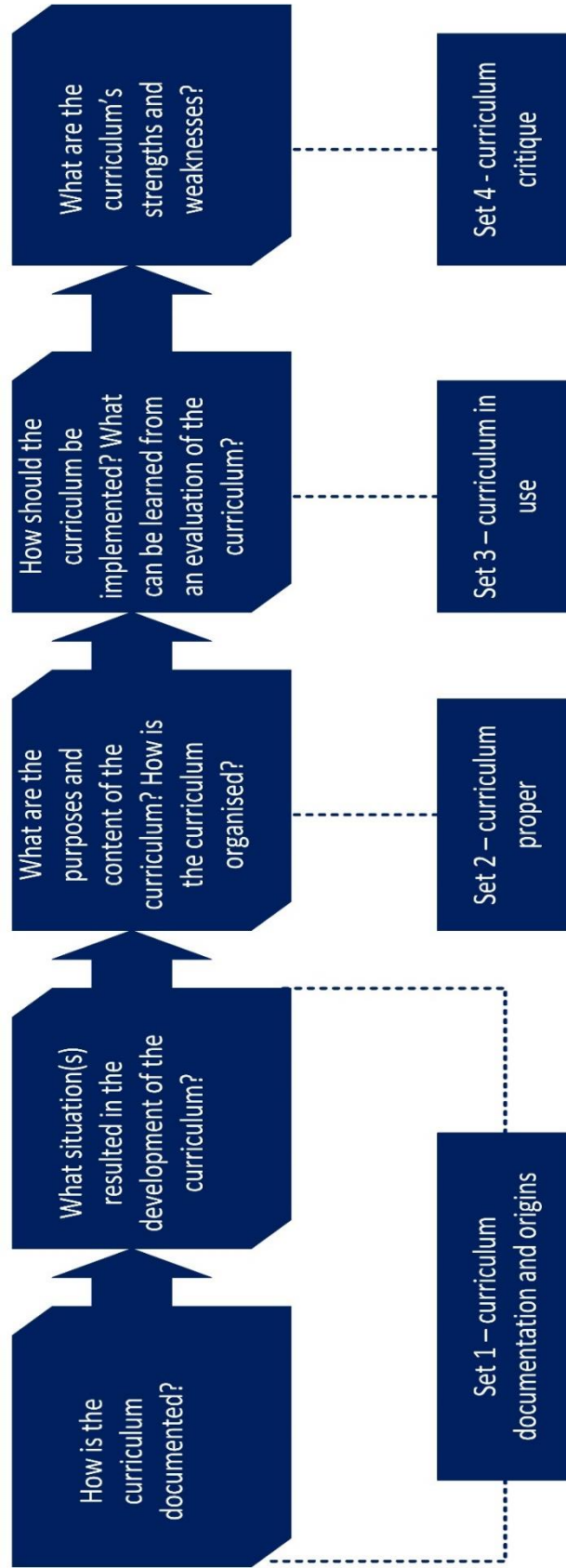


Figure 4.1 Posner's (2004) curriculum analysis process

The second, an experiential approach, has the development of the individual as the primary purpose of education and, by definition, the curriculum. The subject matter will come from real life and from the experiences of children, which, according to Posner, *'emanates from the work of Dewey'* (2004, p.99).

Posner's third approach, the 'structure of disciplines' sees the purpose of education as the development of intellect.

His fourth approach, a behavioural one, sees the content of the curriculum as a set of skills that are measurable.

His fifth approach is a constructivist one where the purpose of the curriculum and its content is to allow the child to construct and develop meaning from the curriculum as taught. All these will be borne in mind in this analysis to try to ascertain if any one approach is discernible.

Posner's (2004, pp.20-21) 'second set' underpins the analyses presented in Chapters 6, 7 and 8. The key questions from Posner's second set are:

1. What are the purposes and content of the curriculum?
2. What assumptions underlie the curriculum's approach to purpose or context?
3. How is the curriculum organized?
4. What assumptions underlie the curriculum's organization? (Posner, 2004, pp.20-21)

The questions from Posner's framework for analysis support the research questions set out on page 63. Posner's question 1, the purposes and content of the curriculum is related to RQ 1 and 2, which asks about the origin of the curriculum, its development and what influences there were on the curriculum. Posner's Question 2 also links with RQ 2 as the various political, educational and organisational influences may lead to assumptions being made about the structure and content of the curriculum. Posner's Question 3 directly relates to how the curriculum was set out by the subject working groups and the requirements of the politicians who set the curriculum project in motion initially, which is pertinent to RQs 3 and 4. This also applies to Posner's Question 4 which asks about any assumptions made about the curriculum and its organization.

The choice of Posner's framework for the analysis is based on the importance of understanding the various situational factors that contribute to the development and construction of a curriculum. Posner stresses this in his work and the use of the various 'sets' allow for discussion of these factors. The model proposed by Posner allows the curriculum being analysed to be 'unpacked' so that how it relates to learners and

teachers can be made explicit as well as how it deals with knowledge, processes and skills. There is also the cultural and societal aspect, which can be examined within the various 'sets'.

#### 4.17 Document analysis

Bowen (2009, p.27) defines document analysis as '*a systematic procedure for reviewing or evaluating documents*'. He continues, stating that the purpose of document analysis is '*...to elicit meaning, gain understanding, and develop empirical knowledge*.' For this research a number of documents were analysed (appendix A). Bowen (2009, pp.29 - 30) lists five specific uses of documents in qualitative research:

- 1) To provide data on the context within which research interviewees operate.
- 2) To suggest questions that may need to be asked as part of the research.
- 3) To provide supplementary research data.
- 4) To provide a means of tracking change and development.
- 5) To provide a means of verifying or corroborating evidence from other sources.

As a source of evidence, documents have several strengths. For this research, the various draft and published versions of the SNC are key documents. They represent a stable record of what was expected to be taught or incorporated in science education schemes of work in schools. The documentation is specific in that it relates only to science (or the sciences taught) and it is specific geographically, covering England and Wales initially, then England only after Wales gained independence and control over its own education provision in 1998. The documents are also independent of this case study, that is, they were not created especially for use within the research.

Other documentation analysed includes Government policy and statutory documents, reports on science education from organisations such as learned societies, the Office for Standards in Education (OFSTED) and independent researchers. Using documents as a source of evidence also has associated weaknesses. For example, the document may display the bias of the author (see later, section 4.17.2, media analysis). The availability of documents may provide a selective range that is not a true representation of the available document sources of the time as some documents may not have been kept or archived.

Document analysis is able to add depth to the research process, it is something that is not always '*fully exploited*' (Simons, 2009, p.63), but is capable of adding a degree of richness to the data and will be very helpful in developing explanations and an understanding of how the NoS was conceived and used (or ignored) in science education.



#### 4.17.1 Document analysis process

Many documents can be found relating to the history and development of the NC and the curriculum for science. Documents, while informative, do not provide first-hand evidence of how policies, statutes etc. were implemented in schools and classrooms. They signal intent, but do not provide evidence of the curriculum 'in action'. It is also the case that authors of the various documents under scrutiny will have their own bias, preferences, knowledge and understanding that may, or may not, be immediately apparent in the written text. Policy is also produced through contestation and negotiation and some of those involved with policy will have a more dominant voice than others, e.g. if a policy comes directly from a Government minister it will be heavily influenced by that minister. Other policies may come via special advisers within a government department and such policies can be heavily influenced by the advisers. A recent case in point would be that of Dominic Cummings who held an influential post as a special adviser within Michael Gove's office during part of his time as Secretary for State for Education between 2010 and 2014 (Millar, 2013). What is left out of documentation (or what could have been excised during a review and editing process) is unknown and can affect how the document is finally viewed/interpreted and implemented by its intended audience.

To ensure the analysis of the documents was consistent and elicited relevant information for the case study, a document analysis record and log (see table 4.1 and appendix B) was created for each of the documents sourced as potentially relevant to this case study. The log was devised by adapting and combining key aspects and questions from a range of online document analysis templates across a variety of subjects e.g. medicine, history, politics etc. The completed logs served as a record and means of deciding which documents needed to be included/excluded from the case study.

#### 4.17.2 Media analysis and political biographies

For this thesis, use was made of newspaper reports and the biographies/autobiographies of politicians. These were read and analysed with an acknowledgement of potential bias. For example, it is widely known that newspapers will have an ideological viewpoint and will, therefore, report from this perspective. Newspapers that are traditionally Conservative in outlook, such as the *Telegraph* and *The Times* and those that are more centrist, such as the *Guardian*, must be read with such a bias in mind. For this thesis, not all newspapers were used as sources of reporting on the NC. *The Sun*, *Mirror*, *Daily Mail*, *Mail on Sunday*, *Daily Express* and *Sunday Express* were excluded. These newspapers tend to be more sensationalist and do not give depth of coverage. The key newspapers searched were *The Times*, *Guardian*, *Telegraph* and *The Independent*, plus their associated Sunday publications. The *Times Educational Supplement* (TES) is

another potential source of news reporting on events. There is no digital archive for the period covering the introduction of the NC. The digital archive begins in 1999. The TES was excluded from the analysis on this basis as access to the print archive was difficult, costly and only 50% (roughly) of the period being researched could be reviewed online. Where TES stories have been cited, the content was specific and relevant to any argument being made.

Table 4.1 Document analysis log aspects

Aspect	Related analysis questions
Document Title	Record the full document title
Document Origin	What organization/who published the document? Where was it published?
Authors	Who authored the document? What is their affiliation?
Document Date	When was the document published?
Intended Audience	Who was the document written for? (Teachers, politicians, academics, education experts, education leaders etc.)
Contextual Information	What was the political context at the time the document was produced? What was the educational context at the time the document was produced?
Document Purpose	What was the intended purpose of the document? (information, consultation, statutory, evaluation, professional analysis/viewpoint etc.)
Document Content	List the key information the document provides
Document Deficiencies	What does the document <b>not</b> say that you expected to be said?
Document Classification	Is the document a research report/ Government document/ policy/ statute/ green paper/ white paper/ curriculum document/ evaluation/consultation etc.
Document format	Article/online/booklet/report etc.
Document reliability	Is there a set of citations/references? Does the document lead to other useful documents?

Another issue in the use of newspaper reports is that the agenda of the journalist, that is, the type and number of questions (with or without follow-up questions) will be set by the journalist rather than a researcher. The key to good journalism is to create a 'story' that will capture the reader and that the reader will wish to read in full. It is not the intention of a journalist to capture an accurate historical record of what is happening.

In viewing and analysing other reports from organisations such as HMI, OFSTED etc. it was acknowledged that although these are 'independent' organisations they would, nevertheless, be reporting on or monitoring the progress of the Government curriculum and standards within the various subjects, including science as a key or core subject. There may be a bias towards Government or there may also be a bias introduced by the author(s) unconsciously.

In the case of Government documentation and reports, care needs to be taken in understanding how these reflect the actual situation. With Government documents, there is a definite chance of bias as Government seeks to report or record those things that can be promoted as 'successful' implementation of policy, to make a case for putting to the electorate that any policy ideas suggested, then legislated for, have been a success regardless of the evidence. It is a case of playing down, even hiding the negatives and overstating the positives.

The introduction of a NC was a key education policy for the Conservative party. The media extensively reported on the lead up to and implementation of the 1988 ERA. Media reports provide a view on how policy is being implemented and received by political parties, teachers, unions and other stakeholders. As such, an analysis of these reports will add to the formal document analysis allowing for a more nuanced analysis.

Biographies and autobiographies of politicians will be written from the perspective of that person. As such they provide a view of the 'reality' of what happened during their terms of office which will naturally project their own contributions in a positive light. Accounts of the actions and views of other politicians will also be from their personal perspective. These accounts, while not bias free, are still important given that major theme within this thesis is political influence.

#### **4.18 Semi-structured interviews**

A curriculum is enacted by teachers and experienced by children. The main purpose of the interviews in this case study was to understand the experiences and reflections of a small sample of people taught science during the implementation of the SNC. I wanted

further to try to understand how some teachers, who had been taught under the SNC, viewed the NoS and the scientific method.

The interviews were not intended to gather data to form an opinion on how well science teachers understood the NoS or TSM and neither was it about trying to fulfil Posner's (2004) set three – the enacted curriculum – for the curriculum analysis framework. It has already been established that teachers' conceptions of the NoS is flawed, limited, even confused (Abd-El-Khalick, 2013; Bayir *et al.*, 2014; Kremer *et al.*, 2014; Mihladić and Dogan, 2014; Rudge *et al.*, 2014; Sumranwanich and Yuenyong, 2014; Demirdogen and Uzuntiryaki-Kondakc, 2016).

As science teachers, the interviewees would have an educational influence over how a curriculum was enacted. This will differ from the educational influence of those who developed the SNC and those who revised it. The interviews were designed to prompt the teachers to reflect on their experiences of science and articulate their understanding of aspects of the NoS and TSM.

The interviewees were randomly selected for interview from a range of science teachers who expressed an interest in the project, following a general call for interviewees via a general e-mail to science teachers in the Sussex Education ITT Partnership, personal contacts and science teachers on social media (e.g. Twitter). The interviewees were drawn from a range of subject disciplines. All the selected interviewees were given alternative identities (see confidentiality and anonymity later).

In selecting interviewees, I needed to ensure that science teachers well known to me, who I trained as science teachers, or who were very aware of my work on the NoS did not form part of the group. Having written a book (Williams, 2011) that deals with several aspects of the NoS and TSM as well as running training sessions for ITT explicitly dealing with this topic, those teachers would be more likely to provide answers to questions that they knew, consciously or sub-consciously, would align with my own views. This was one way of trying to eliminate some bias within the process. One volunteer for interviews, for example, was a former student who had read my book and who I had supervised for her MA dissertation, which was based on aspects of the NoS. While she was a useful contributor to the pilot phase, she could not form part of the sample of teachers and there would likely be a bias to her responses that would favour my own thoughts and views. The questions for the interview were also trialled with other current and past trainee science teachers to test possible responses and to refine the questions so that they did not introduce an unconscious bias.

#### 4.18.1 The interview formats

The format chosen was a semi-structured interview. The choice of format is important, as this will determine the type of data gathered. Semi-structured interviews are flexible. A sequence of defined questions can be pre-prepared but other questions, which may arise from any interviewee's answers during the interview, can be asked and related avenues explored. As O'Leary (2014, p.218) says, it allows questions to '*...shift in order to follow the natural flow of (the) conversation. Interviewers may also deviate from the plan to pursue interesting tangents.*' This approach also allows for unintended data to be gathered, that is, interesting data that may otherwise have been missed if a very structured questionnaire or set of verbal questions is asked. Cohen *et al* (2013, p.412) see the selection of interview format as being about '*fitness for purpose*'. The format chosen has several key characteristics that make this form of interview appropriate. For a case study these characteristics are: engagement, which leads to an understanding and interpretation of the key features of the lives of the interviewees; the use of natural language (although science specific terminology was a feature); the ability to reveal and explore nuanced descriptions of interviewee experiences and a focus on specific ideas and themes (Kvale, 1996 cited in Cohen *et al*, 2013, p.414).

#### 4.18.2 Planning the interviews

The planning process for the interviews began with consideration of the target group (science teachers), the sample (a small sample from across the 'three' main science disciplines) and access to the sample (one-to-one or via various communication technologies – Skype™, 'phone etc.). The next step was to plan the full procedure by implementing the following stages: thematising; designing; interviewing; transcribing; analysing; verifying and reporting (Cohen *et al.*, 2013, p.415).

#### 4.18.3 Thematizing

The main objective of the interviews was, as noted above, to elicit the experiences of teachers who themselves were taught primary and/or secondary science through one or more versions of the SNC. It also sought to establish an understanding of TSM, the NoS and specific terminology related to the NoS. Themes such as reflections on experiences in science as a child, teenager, adult, understanding of TSM, the use of scientific language were the initial driving themes. The questions were assigned to the following categories as listed by Cohen *et al* (2013, p.417): background; experience; knowledge and descriptive questions.

#### **4.18.4 Designing**

This involved the production of an interview schedule then a pilot interview to test the questions. There was a review of the questions post pilot to adjust and confirm their suitability for gathering data on the intended themes (above). The questions were designed to allow the interviewees to provide rich descriptions of their views, ideas, reflections and memories of science as well as their understanding of some aspects of science such as TSM and the NoS. An interview schedule was produced and used for each separate interview to ensure consistency in the order and wording of questions asked (appendix C). The interviews gathered data with a view to informing the responses to the research questions set out on p.62. The 'memories of science' section elicited responses on the teachers' memories of doing science in both formal (school) and informal (home) situations. This was related to RQ 2 which asks about the educational influences on the science curriculum – that is, how was the curriculum taught and were the teachers aware of the fact that they were even doing 'science' in primary school or were there aspects of the teaching of the science that they could clearly identify as being from the SNC? Other sections of the interview were probing the teachers' understanding of the NoS, for example: descriptions of TSM; science in society and language related to the NoS. These sections related to RQ 3-6 which examined how the NoS was articulated in the SNC as well as how it changed over various versions of the SNC. Gaining an understanding of how the science teachers' articulated their views on the NoS informed the case study by providing examples of how the NoS is viewed by science graduates who were taught in schools delivering the SNC. It is also acknowledged and understood that their further study in science to degree level and/or work as a scientist will also influence this view.

#### **4.18.5 Interviewing**

The selected interviewees were fully briefed prior to the interview and provided with an outline of the project and procedures and an interview consent form to sign giving permission for the interviews to be recorded and the data generated used in the thesis (see appendix D).

The interviews were conducted in person in two cases, via Skype™ in a third case and by telephone in the final case. There was a mix of formal and informal settings. Although the interviews were planned to be as informal as possible, in the case of face-to-face interviews, it was a more formal set-up as these took place at the interviewee's place of work. The interviews were individual rather than group in a bid to encourage openness and freedom of expression from the interviewee (O'leary, 2014). In all cases the purpose of the interview was explained, the conduct of the interview and how it was structured

etc. The fact that it was to be recorded, transcribed and analysed was explained as well as there being no expectation on my part that there were 'right' or 'wrong' answers to any of the questions posed. The interviews were designed to last no more than 1 hour, most were conducted in about 45 minutes.

#### **4.18.6 Transcription**

The recordings were first machine transcribed from voice to text. The machine transcriptions were edited to ensure that a 'script' was produced (see appendix E for a sample) that reflected and distinguished accurately the researcher from the interviewee. Recordings were played several times and then edited to eliminate errors in transcription. This process allowed me to gain familiarity with the interviews and an idea of the broad themes being generated. To avoid loss of contextual data and to recognise the fact that each interview was a social encounter, context and body language that could be important for interpretation were noted. The notes made at the time of the interview were checked and, where relevant, added to the interviews e.g. the addition of 'air quotes' when used by one interviewee, or a significant pause or look indicating 'confusion' in another case.

#### **4.18.7 Analysing the interviews**

To aid with analysis NVivo software was used during the coding and re-coding phases. Figure 4.2 summarizes the process used. The semi-structured interviews were analysed using a thematic content analysis approach (Braun and Clarke, 2006; Kohlbacher, 2006; Creswell, 2014; Elo *et al.*, 2014). The transcribed interviews were coded and reviewed several times to elicit the key themes arising from the questions posed during the interviews (see appendix F for a detailed example of one round of analysis related to the transcripts). Broadly, four major themes emerged from the interview data:

- memories/experiences of science;
- reasons for taking up science;
- descriptions of the scientific method (TSM);
- understanding of key scientific NoS terminology (the language of science).

The interviews were analysed with respect to the main themes running through the thesis (political, educational and organisational) as well as identifying themes that resulted from the analysis of the statement on the NoS from the first draft SNC (DES, 1988b). The interviews gathered information, in the form of interviewee memories/reflections, about the life experiences of the interviewees as children studying science and explored their progress in science from school to university and then on to work, including their current work as science teachers. The first part of the interview consisted of prompted memories

of their experiences of science in the home, during their time in primary education, secondary education as well as post-statutory schooling in university and/or work. This was followed by questions on TSM, the NoS and the language of science (appendix C).

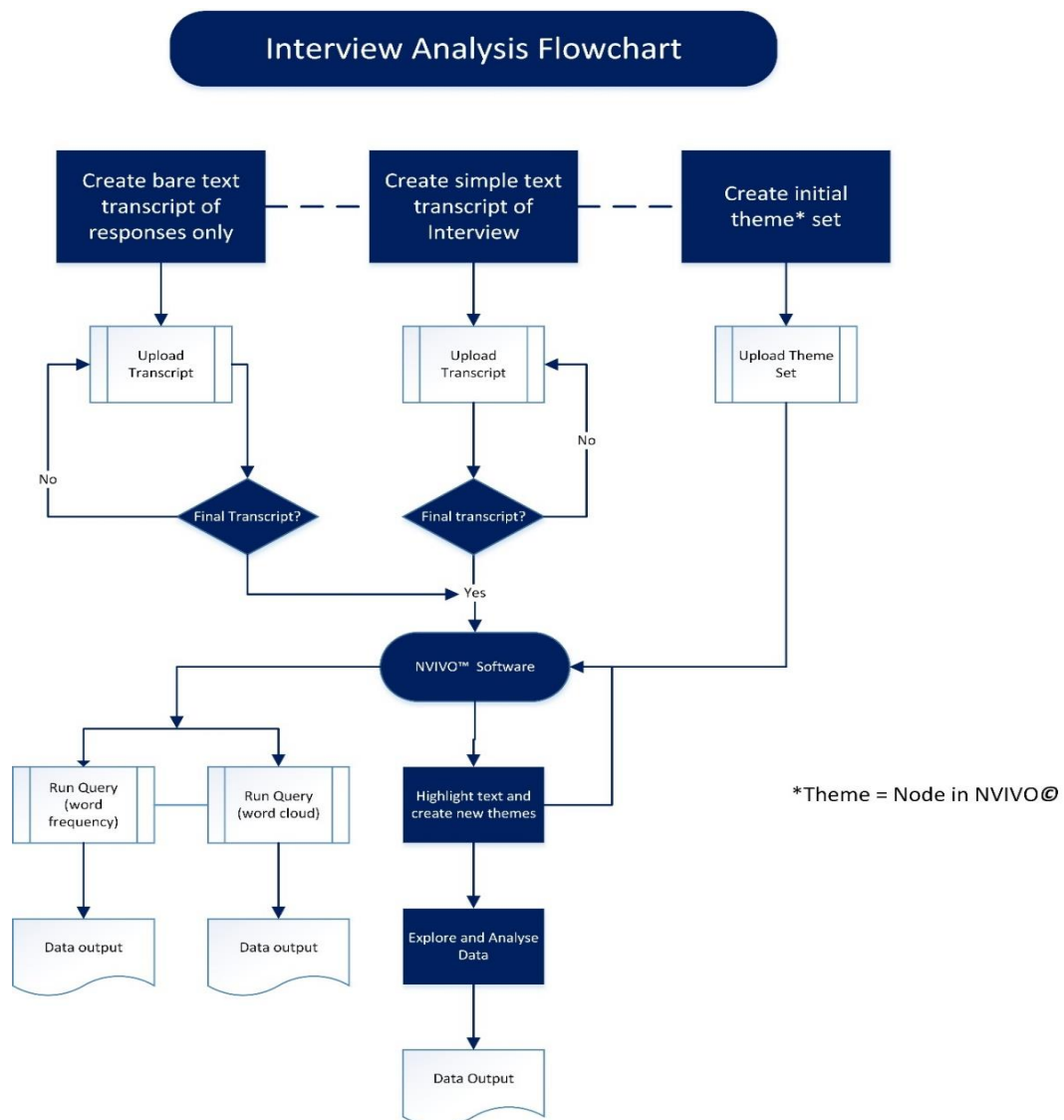


Figure 4.2 Flowchart to describe the interview analysis procedure

As has been noted by others (Shacklock and Thorp, 2005; Tedder, 2012), the memories as recounted will be selective. For those interviewed, it is the ‘truth’ as they recall and remember it, but it will not be an objective truth. All their recollections will be subject to change over time and the person recounting their own experience will have their own interpretation of events that may well differ from others who were involved (had it been possible to interview others – teachers or pupils - directly involved). Even with these limitations, constructing an experience and then fleshing this out with context derived



from the changing nature of the school curriculum will provide an interesting, though not generalizable, set of observations about how a curriculum and its interpretation by a few teachers may have influenced some children (the interviewees) over their choice of subjects and interest in science. The use of these experiences and life histories, even in a limited way is, as Denzin (1989, p.73) notes, not without problems, *'No self or personal-experience story is ever an individual production. It derives from larger group, cultural, ideological, and historical contexts.'* Denzin (1989, p.74) elaborates on this saying:

A story is always an interpretive account; but, of course, all interpretations are biased. However, many times a storyteller neglects important structural factors which have impinged on his or her life.

In view of this important consideration, the experiences will be explained in this analysis with reference to the prevailing context within which teachers and schools were working with respect to the SNC. These are then linked to the common threads of the political, educational and organisational factors that affect the curriculum. The thematic content analysis (TCA) of the data gathered in the interviews was carried out in six stages (Braun and Clarke, 2006). The stages are set out in table 4.1.

#### **4.19 Problems associated with interviews**

While interviews and transcriptions provide a way of capturing a holistic, rich dataset, they are not without issues. Interviewers may influence the interviewee depending on any previous relationship they may have with them. The interviewees in this case study had little to no previous relationship with me as a researcher or science educator though one was aware of work I had previously done within science education (writing a series of textbooks on science for Key Stage 3 children). In the transcription process, it is known that communication is more than just the words spoken, there is intonation, emphasis and non-verbal communication e.g. expressions, gestures etc. These were, where possible, noted at the time. If there were significant pauses these were also noted. As Cohen (2013, p.426) states, *'there can be no single 'correct' transcription; rather the issue becomes whether, to what extent and how a transcription is useful for the research.'*

Table 4.1 Thematic content analysis stages

Stage (S)	Action	Result
S1	Read/re-read data gathered in interviews and across the documentation to familiarise myself with the content and begin to see any patterns that emerge.	Initial coding will be developed
S2	Using NVivo the initial data codes will be used to reduce data through highlighting where and when the various patterns are found. The patterns will be related to the research questions. At this stage some initial inferences from the data will be drawn out to generate meaning from the data.	Comprehensive codes of how data answers research question.
S 3	The initial data codes will then be collapsed into clusters to provide overarching themes that represent the data content.	A 'long list' of themes will be generated.
S4	The themes will be further analysed with respect to the overarching theoretical perspective of Posner's curriculum analysis and the use of 'professional language'.	The construction of a descriptive narrative
S5	Theme definition, generating 'definitions' for the themes and final names	The themes will capture a common, recurring pattern across the dataset.
S6	Reporting the findings	A comprehensive analysis of what the themes contribute to understanding the data, related to the research questions

#### 4.20 Reliability, validity and generalizability

Thomas (2011, p.62) asks an interesting question when it comes to issues of validity and reliability; '*Do I have to worry about validity and reliability in a case study?*' His answer is a simplistic and categorical '*no*'. He admits that this is not a universal response to the question and that others will question his simple dismissal. His response is interesting. He notes that issues of reliability and validity have been imported from other research paradigms (he mentions applied psychology). He asserts, correctly in my view, that in such disciplines, instruments used to measure certain features do, in practice, need to be reliable and have a degree of validity. The idea is that the same instrument (e.g. a questionnaire) should be able to elicit similar outcomes in different study populations. A case study, Thomas (2011, pp.62-63) argues, is very particular and only examines a particular '*thing*' at a '*particular time*', by a '*particular researcher*'. There is nothing to say that the same '*thing*' if investigated by another researcher at a different point would result in similar, or the same, outcomes.

Simons (2009, p.128) does, in part, concur with Thomas. She is not as categorical but warns that in attempting to ensure reliability and validity of your data, by meeting criteria not meant for social sciences, there is a danger of '*straining the data to meet the concept and losing the meaning in the process*'. As a science graduate, I have an affinity for validity and reliability in data but can see perfectly well the issues that Thomas and Simons point out.

To address this, issues of validity and reliability were taken on board during the design of the document analysis process and the construction of the survey schedules e.g. the use of a pilot and the careful selection of interviewees, but overall it would be wrong and improper to claim complete reliability or validity for any of the processes. Simons (2009) has a point, that ensuring complete validity and reliability would have the effect of distorting the data. Thomas (2011) dismisses too easily the concerns, but also has a point when he claims it is not something to worry about too much.

Generalizability of case study research is also a contentious issue. A general concern, noted by Swanborn (2010), is that case studies cannot lead to generalizations. Others contest this view. Yin, for example, takes an interesting stance by thinking about what we mean by 'generalization'. He considers two types, statistical generalization and what he terms analytic generalization. The latter, being generalizations that inform theoretical concepts used in the design of the case study, or that result in new concepts that arise from the case study on completion (Yin, 2013). Simons (2009, p.164) has a view, which I agree with, that is, case studies are not about producing generalizable results, but are more about how we can '*demonstrate how and in what ways our findings may be transferred to other contexts or (be) used by others.*'

#### **4.21 Strengths and weaknesses of the approach taken**

The NoS is a complex concept with a long history. It is neither discipline bound (it is something studied within natural science and philosophy of science for example), nor is it exclusive to those who are identified as 'scientists' (the public will have their own understanding of the nature of science, even if individuals do not call it that). It forms part of the current English SNC and exists in other science curriculums across many other countries. This of course begs the question – does a single agreed and uniform definition or description of the NoS exist? As Lederman (2007, p.832) says:

Even though explicit statements about the meaning of the NOS are provided in well-known documents... the pages of refereed journals and the conference rooms at professional meetings are filled with definitions that run contrary to ...reform documents. Some would argue that the situation is direct support for

the idea that there is **no** agreement on the meaning of NOS. (Lederman's emphasis)

Lederman goes on to dismiss the idea of 'no' agreement and argues that there is more agreement on aspects of the NoS than there is disagreement, as noted in Chapter 3. This is one of the potential weaknesses of the research carried out. Rather than finding out how the curriculum and interviewees' ideas 'match' with general and accepted understanding of the NoS, all interpretations of the NoS could have equal weight. Despite the lack of universal consensus, I concur with Lederman that there are key features of the NoS that many interpretations from across the disciplines rely upon (as outlined in Chapter 1). In this respect, the weakness is less troublesome.

Another possible weakness surrounds the range and types of documents used and whether these represent an unbiased and 'complete' sample. This research is bound by a specific time-period and the main documents being evaluated are official documents. This means that issues of, for example, political ideology that may affect the content of the statutes and policies can be 'known' and made explicit. Reports written to meet the needs of the curriculum will inevitably reflect the authors' 'understanding' (or not) of the NoS and the presence or absence of any reference.

The small sample of science teachers interviewed could also be cited as a potential weakness. The purpose of this research is not to generate data on a general understanding about, for example, the NoS of a representative sample of science teachers (as noted earlier), but to elicit the understanding of aspects of science in individuals and to see how this understanding matches the conceptions of the policy, curriculum etc. There exists a large body of research on teachers' conceptions of the NoS (see, for example, Celik *et al.*, 2006; Liu and Lederman, 2007b; Abd-El-Khalick, 2013; Wan *et al.*, 2013; Sarriddine and BouJaoude, 2014). A larger scale study here would not necessarily add value to the corpus of knowledge that already exists.

The strength of this research lies in the fact that it is a bound case study with specific parameters that examines a specific issue and seeks to explain and generate understanding of how the NoS has been incorporated into our science curriculum and how it is understood in practice by some teachers across the science disciplines.

Although the findings are not generalizable, they will provide a better understanding of how (even if) the NoS is made explicit within a curriculum. It will offer opportunities to discuss what curriculum changes may be needed to strengthen our science education

and what may be needed in our ITT courses for science teachers in order to improve or refine their understanding of the NoS.

#### **4.22 Ethical considerations**

In conducting the interviews, it was important that ethical considerations were fully understood. Due process was followed to obtain full ethical clearance via the University of Sussex ethical review system (appendix G).

In obtaining ethical clearance and in constructing the questions and procedures for the semi-structured interviews, the BERA ethical guidelines for educational research were used (BERA, 2011). As the researcher, it was my responsibility to '*operate within an ethic of respect for any persons involved in the research*' and to ensure that all the interviewees were '*treated fairly, sensitively, with dignity, and within an ethic of respect and freedom from prejudice*' (BERA, 2011, p.5). There were three guiding principles followed when considering the ethics of this research; minimising harm, protecting privacy and respecting autonomy (Coe *et al.*, 2012; Cohen, 2013; O'leary, 2014).

The procedures for the semi-structured interviews were put in writing and clearly explained to interviewees before any interviews proceeded (as noted earlier). The interviewees were provided with a written version of the procedures (appendix D). The mode of interview (e.g. by 'phone, Skype™ or one-to-one), location, communication method and timing was agreed and decided in advance with the Interviewees, this was done to ensure privacy, to respect their working commitments and ensure that minimum inconvenience to the interviewee arose.

##### **4.22.1 Informed consent**

Informed consent was required for this research. Following the general guidelines from BERA, and more specific discussions of informed consent by Cohen *et al* (2013, p.80), details of the research, its purpose and procedures were provided to all the interviewees in advance of any formal recorded interviews. Verbal Informed consent was sought in all but one of the recorded interviews, as well as in a written format. In reviewing one of the recordings, it was apparent that while I thought at the time I had captured a verbal informed consent, I had not. Interviewees were asked to return signed consent forms (appendix D1) that indicated they had read about the purpose of the research, the context within which the interviews would be used and some possible outcomes from the research. One interviewee did not return a signed permission document (see below).

#### **4.22.2 Withdrawal of consent**

Each interviewee was informed in writing of their right to withdraw from the research/interview prior to the interview taking place. Withdrawal could take place at any point up to July 2016, at which point the data would have been analysed and incorporated into the thesis and it would be difficult to extract individual data easily (appendix D and D1). One interviewee did exercise this right (see section 4.23).

Interviewees were also informed at the start of the interview that they were free to end the interview at any point, without having to provide a reason, or to refuse to answer any question, again with no questions asked about reasons for declining to answer. They were also reminded of their right to withdraw post interview as described above. The right to withdraw or not to answer questions was important, as some questions required them to reflect on their childhood as well as their school experiences. With no knowledge of their personal circumstances and backgrounds, there may be issues from childhood, family, schools etc. that they may not wish to reflect upon or discuss. The questions posed were general, rather than specific, allowing the interviewee to decide on what information they wished to disclose. All interviewees were offered transcripts of their recorded interviews should they wish to have one. Only one interviewee asked for a copy. This led to an issue with the use of the interviewee's data (see section 4.23 below).

#### **4.22.3 Anonymity and confidentiality**

Anonymity was an important aspect of the interviews. Any names used, including the names of schools that the interviewee attended as a child, did placement experience in, or the name of their current workplace are not used within the thesis. Only vague descriptions of the school type or area are used, any names used are pseudonyms. To further aid anonymity, where interviewees used the names of teachers they referred to as being influential in their own education, this has been reduced to a random initial letter. A title is used to identify only if the teacher was male or female e.g. Mr/Miss.

Given the small number of interviewees, it is very difficult for an individual to 'hide' within these data. The only way to ensure complete confidentiality would be to disguise the responses to such a degree that they would become unrepresentative and not useful. As Cohen (2013, p.93) explains:

...more problematic is the question of what confidentiality actually means if the data are to be used for the research; if data are to be confidential and cannot be used or passed on, then what is the point of collecting or having the data? In this case it is perhaps anonymity that should be addressed rather than confidentiality, or that the scope of confidentiality (its boundaries) should be clarified rather than a guarantee be given of absolute confidentiality.

None of the interviewees were known to each other, as far as I am aware, and the names of the interviewees were not disclosed to each other at any time. While an interviewee may recognise their own input, they would not be able to identify any other interviewee or have the means to deduce from the data/thesis the whereabouts or identity of any other interviewee who was taking part.

#### **4.22.4 Data protection**

The interview data were recorded digitally, with copies transferred and held on my University computer personal drive. No other copies have been produced or stored. Only I, as researcher, had access to the recordings. Initial transcription was done via machine transcription of voice to text. Once the files had been transcribed, they were deleted from the online software. The true identity of the interviewees is only known to me as the researcher. Once the thesis examination process is completed, the recordings will be deleted and notes shredded.

#### **4.23 Issues arising from a lack of consent**

The key ethical consideration for this investigation was that it should do no harm, either to the researcher or those involved with and reported on in the research. The project was classified as a low risk one that involved limited fieldwork and a small number of adult professional interviewees who could give informed consent.

Two issues arose from the interviews. The first was related to permission to use the data. The second, a more difficult issue relating to a potential undermining of confidence of one of the interviewees.

##### **4.23.1 Lack of permission**

In one case, an interviewee failed to provide the necessary permission to allow for the inclusion of their interview data. The interviewee was sent reminders by e-mail to return the signed permission document, which remained unanswered. The interviewee was unable to be contacted directly by 'phone. Despite messages left, calls were not returned. Although there was verbal permission given, unfortunately this was not recorded (see earlier). A judgement was made that continuing to try to obtain permission could constitute a form of harassment and the decision was taken, in accordance with the BERA (2011) guidelines, not to place the interviewee under duress to provide the required permission. As a result, notes taken along with the recording were deleted/destroyed. No data from this interviewee contributes to any part of this thesis.

#### **4.23.2 Undermining confidence**

In a second instance, while permission was granted verbally and in writing, later the interviewee decided to withdraw from the research project. In a 'phone call to the interviewee (which was not recorded), it transpired that the interview had, after a time, undermined the interviewee's confidence in their knowledge and understanding of some basic, key elements of science. One section of the interview considered the language of science and how we define some of the key terminology used. During the interview, the interviewee was unclear about some definitions and confused over others. In a second section on TSM the interviewee simply provided a rubric for 'doing' a science experiment. The interviewee had asked for a copy of the interview transcript and on reading this back decided to withdraw their contribution.

It is clear to me that the interviewee's confidence had been undermined. In this case I listened again to the interview to see if, as the researcher/interviewer I had contributed to undermining the interviewee's confidence through any inappropriate remarks or any inappropriate comments which may have indicated that the interviewee 'should' have known the 'correct' answers. I confirmed that towards the start of the interview I had made the statement that there were no 'right' or 'wrong' answers to any of the questions and that I was gathering the interviewee's views, reflections and experiences in science and science education. Having conducted similar research in this area previously (Williams, 2013) I was aware that many different, often vague definitions can be provided for these terms even by science graduates and that an understanding of TSM was neither common, nor agreed, amongst science teachers (let alone amongst scientists generally). In the interview, the interviewee apologised for being 'vague'. I commented only to stress that vague, wrong or confused definitions etc. were common and there was no need to apologise.

During the later 'phone call, the interviewee asked if I could provide help and information on those aspects in which they felt they had an insecure grasp. I provided some helpful reading and links via e-mail. By return, they thanked me for the information etc. and reported they now felt more secure and happy about the subjects under discussion. Out of embarrassment, they explained, they still preferred to withdraw their contribution, a request that was fully complied with by me.

This incident brings up an issue of the sensitivities of asking professionals about their professional knowledge and understanding. On reflection, should I carry out further research in this area, I will reconsider how the start of the interview process is structured to ensure that any future interviewee does not have confidence in their own ability



undermined. It would also be useful, for example, to provide interviewees with reassurances and to offer examples (post interview) of the variation in opinion or understanding that other professionals may have, or to confirm that the research is simply seeking to establish the degree of variation and is not seeking absolute statements.

The incident also underlines the necessity for every interviewee to be fully informed and to feel in control of the data they generate and to be able to withdraw their consent, which is what happened in this case. Such incidents reinforce the need to put the dignity and welfare of any interviewee, no matter the age or level of responsibility they hold, at the forefront of any decisions. As a researcher, you hold a certain position of power, even if throughout you try to minimise this. It is necessary to be conscious of this during all the stages of research.

#### **4.24 Limitations of the Study**

All research has limitations and this case study is no exception. Having completed the study and analysed the data certain limitations are apparent and discussed below.

##### **4.24.1 Interviews of serving teachers**

The initial proposal for this thesis had a wider remit and looked to interview a range of teachers who had been educated under the old non-NC curriculum regime, some who were only educated in NC science at KS3 and 4 and the rest educated completely under various versions of the SNC. It soon became obvious that finding willing volunteers and developing an interview strategy would be too complex. To widen the pool of potential subjects for interview, social media and personal contacts were used to try and find the range of ages, subject disciplines and geographic locations. Finding, then obtaining consent, proved to be a long and difficult process. Teachers, when they were told about the purpose of the thesis i.e. an examination of the NoS, felt uncomfortable talking about this and many opted not to accept an invitation. This may indicate that they felt their own knowledge of the NoS was less well developed. It could also have been a reaction to the fact that some teachers, aware of my previous work in this field, felt uncomfortable talking about it. They may have felt uncomfortable talking about the NoS with someone they regarded as having greater expertise than they do on this subject. Due once more to time constraints, the final pool was reduced to six teachers. Only four were included in the thesis as one failed to provide the necessary signed consent forms and a second had a change of mind with respect to the inclusion of their interview data (see section 4.23.2). This highlights the need for a clear and explicit plan and purpose with respect to including participant interviews. For this research, the plan was not clear enough and the

data gathered from the interviews was not sufficiently focussed to deliver data pertinent to the research questions. Some of the data, with respect to definitions of key terminology backed up a previous survey on this issue (Williams, 2013). On reflection, the interview schedule should have been more focused on the educational experiences and how those related to the various SNC documents. Knowing the age of the participants it would have been possible to work out which versions they had been taught under and from that ask about their experiences. In some ways, the interviews were too mechanistic and did not deliver in enough depth views and opinions that would have allowed a triangulation of their experiences with what was in operation while they were at school.

#### **4.24.2 Separating the various ‘influences’**

A core theme of the thesis centres on the political, educational and organisational influences that interact with the curriculum. These influences are difficult to separate out and apply to the various people involved in making curriculum decisions. Recognising the political ideologies of politicians is easier than recognising if those who construct write and deliver the curriculum have specific political affiliations and/or ideologies. Likewise, there will be educational influences e.g. those who prefer a direct instruction approach to teaching and those who favour more child-centred or ‘progressive’ approach, which will be difficult to ascertain directly from documentation. Using the biographies and autobiographies of the politicians involved in the creation and delivery of the first national curriculum will make clear the political driving forces involved. How the intended curriculum would then be interpreted or enacted by teachers will not be so easy to ascertain, in part as Posner’s ‘set three’ was not a feature of the curriculum analysis that is, the curriculum in action (Posner, 2004). From an organisational perspective, the structure of school timetables will be a matter of individual choice of the schools involved in enacting the curriculum. Recognising that separating these influences is difficult does not necessarily mean that the case study cannot describe influences or offer potential issues with respect to curriculum development.

#### **4.24.3 Interviews of original curriculum developers and writers**

As with the interviews of serving teachers, this research has some limitations when it comes to including the thoughts, opinions and reflections of those who contributed to the development and revisions of the SNC. Inclusion of such data would have added more depth and richness to understanding the various influences that affected the initial and subsequent versions of the curriculum. Not being a full-time researcher restricted my ability to devote uninterrupted time in the data-gathering phase, which would have needed to include tracking down original members of the various groups and expert panels and scheduling the interviews.

#### **4.25 Limitations related to reliability, validity and generalizability**

Further limitations of this thesis relate to issues of reliability, validity, and generalizability which were outlined in section 4.20. As Hamel *et al* (1993, p.23) observe:

...the case study has basically been faulted for its lack of representativeness...and its lack of rigor in the collection, construction, and analysis of the empirical materials that give rise to this study. This lack of rigor is linked to the problem of bias...introduced by the subjectivity of the researcher and others involved in the case.

What criticism of case study approaches often fail to take into account is that, a case study such as this one involves researchers as well as participants, who will have inherent ideological differences. There is no attempt in a case study to try to control variables. There is also no attempt to simplify reality in a reductionist fashion. Case studies will throw up paradoxes, as noted in the quotation above, and will not claim to be able to resolve complex issues – in other words, there are no ‘simple’ answers to the complexity of human thought and actions. The difficulties that are inherent in summarising a case study result not from a lack of rigour in the methods or methodology used or the subjectivity of the researcher, but from the complexities of the reality the case study is trying to describe.

#### **4.26 Summary**

The research paradigm of post-positivist, critical realism, the methodology (a case study approach) and the methods (curriculum analysis, document analysis and semi-structured interviews) were specifically chosen to allow a rich, vivid and relevant description of events to be written, in the form of chronological narratives and analyses. These blend a description and analysis of events which focuses on individual ‘actors’ (politicians, educationists, science teachers and others) as advocated by Cohen (2013, p.290).

The purpose of the analyses is to produce interpretations of the data that are conceptually informed. This is not an attempt to produce a theory, as in grounded theory (Glaser and Strauss, 1967), but it utilises the approach of thematic content analysis (TCA) advocated by Braun and Clarke (2006). This takes a social constructionist approach where the meaning derived from the analysis is constructed into themes, in this case, memories/experiences of science; reasons for taking up science; descriptions of ‘the scientific method’ (TSM) and the language of science as well as the themes of political, educational and organisational influence. These themes are then used to produce a narrative that examines the development of the SNC and how being taught ‘science’ affected a small sample of people who are now themselves teachers of science.

Rather than taking a deductive approach, it is inductive. The TCA analysis is linked to the original research questions (see table 4.2), set out at the start of this Chapter, which were the underlying drivers for the case study.

Table 4.2 Summary of research questions linked to the methods used within the case study

Research Question	Associated Method
RQ 1 What was the origin of the SNC and how did it develop over time?	Analysis of political speeches and reports (e.g. HMI) and historical mapping of the establishment and rise of science as a curriculum subject
RQ 2 What were the political, educational and organisational influences on its origin and development?	Document analysis of Government reports, statutes and policy papers.  Analysis of political biographies and autobiographies of key politicians involved in education policy and legislation.
Sub-questions	
RQ 3 How has the NoS been incorporated into the science National Curriculum?	Analysis of curriculum documents using Posner's curriculum analysis framework.
RQ 4 How is the NoS articulated in the science National Curriculum and does this vision of the NoS promote coherence across the sciences?	Thematic content analysis (TCA) of the statements related to NoS and comparison with research on the NoS generally.
RQ 5 How does the incorporation (or lack) of the NoS affect how different scientific disciplines are viewed by science teachers?	TCA of interview transcripts.
RQ 6 How has the evolution and development of the science National Curriculum affected the NoS and its incorporation into science education?	Mapping and analysis of the various versions of the SNC to establish its position, prominence or dominance in science education.

## Chapter 5

### Analysing the Educational and Political Origins of the National Curriculum

This chapter has two parts. In the first part, there is an analysis of the educational origins of the NC using various reports, from Her Majesty's Inspectorate (HMI) and others, that reviewed educational provision in England and Wales. This is followed by an analysis of the political origins of the NC using the accounts of the key policy makers (politicians) linked to its development. The implications for the NC in general and science specifically will be drawn out.

The analyses are conducted using Posner's (2004) framework for curriculum analysis and document analysis as outlined in Chapter 4. This analysis concentrates on Posner's 'first set', namely curriculum documentation and origins. It addresses part two of the first set, the origin of the curriculum, and the specific question, '*What situation resulted in the curriculum?*'

A summary then draws these two analyses together and addresses specific questions from Posner's framework for analysis. The key themes of this thesis (the political, educational and organisational influences) are highlighted within each analysis.

#### 5.1 Part One – the educational origins of the national curriculum

##### 5.1.1 The 'yellow book': a political review of state education

The 'Yellow Book' was a 1976 report, by the then Secretary of State, Fred Mulley, on state education provision across England and Wales (Mulley, 1976). It looked at the status of the various subjects commonly found in the curriculum. Mathematics, for example, was seen to be a common GCE (O level) subject in schools, but on the status of the physical sciences it reported that '*(T)here must be grounds for dissatisfaction in the lowly position in the list of subjects such as modern languages, and the physical sciences*' (Mulley, 1976, p.11). The report noted that more needed to be done to promote these subjects in primary schools. Even though science had been a part of the curriculum for many years (see Chapter 2), this report found that physical science uptake in public examinations was poor. It implied that the teaching of science had not been prioritised. The report also noted that there was a specific issue in the recruitment of specialist teachers in mathematics and science. This problem was fuelled by the lack of students taking up sciences and mathematics at a higher level and, ultimately there not being

enough specialist graduates coming into initial teacher training, a situation that still troubles the educational and political establishment today.

The 'Yellow Book' is an important document in that it was an internally commissioned and written Government report that reviewed the state of education. It provided evidence and therefore a justification for politicians to pave the way for a 'core curriculum', the forerunner of the NC, as the report states:

The time has probably come to try to establish generally accepted principles for the composition of the secondary curriculum for all pupils, that is to say a "core curriculum". One advantage of the existence of such a curriculum would be its guarantee of relative continuity to children moving between schools in different parts of the country. The creation of a suitable core curriculum will not, however, be easy. Pupils in their later years [of] secondary schooling (up to and beyond the age of compulsory attendance) have a wide range of interests and expectations, and suitable provision will have to be made for vocational elements within school education for those who will benefit from this. Extensive consideration and consultation will be needed before a core curriculum could be introduced (Mulley, 1976, p.11).

The 'Yellow Book' provides early indications of Government entering the world of curriculum, assessment and accountability. Politicians at this point had no direct control or influence on the curriculum or assessment. HMI was identified in the 'Yellow Book', as the mechanism for change in core subjects like Science:

HM Inspectorate can step up their efforts through publications, courses and assessorships. The possibility of outside enquiries into these areas of the curriculum, or aspects of them, will be considered at the same time (Mulley, 1976, p.23).

What this report identified was that the educational influences (i.e. teachers, curriculum writers etc.) on science uptake was not working, political influence was indirect and at 'arm's length'. HMI were seen as the agents for change organisationally and politicians were keen to use their influence to improve science uptake.

### **5.1.2 Callaghan's Ruskin speech**

On the 18th October 1976, James (Jim) Callaghan (1912–2005), then Labour Prime Minister, gave a speech at Ruskin College, Oxford. While The Yellow Book is not regarded as the origin of Callaghan's speech (Chitty, 1991), there is no doubt that a synergy exists between the report and the eventual speech produced for Callaghan by the Government policy unit at number 10 Downing Street. It was a statement of the 'reality' of state education at that point in time. Callaghan's speech was designed to expose this reality and to challenge the fact that accountability in education was not really

being achieved. A common core curriculum, revised examinations and an inspectorate charged with monitoring and checking education provision would supply that accountability. Callaghan believed that the time was right for education to be no longer the preserve of teachers and unions. These signal important changes. Callaghan identified that HMI was ineffective in bringing about change (despite the 'Yellow Book' identifying HMI as the possible agents of change) so he proposed an organisational change to HMI to make the inspectorate one of the mechanisms of accountability working on behalf of the Government to monitor schools.

By the early 20<sup>th</sup> Century it was estimated that more than one hundred different examinations existed which controlled entry to many professions and universities. There was no overall control over the variety, content or standards for these examinations (Tattersall, 2007). Leading up to the public examination years, there was no political control over the content taught in various subjects, or for that matter control over exactly what subjects should be on offer or taken by children. The existence of these examinations drove the development of the curriculum subjects by teachers based on their own educational judgement. The rationale for public examinations was suitability to study those subjects at post 16 and at university level. It was not necessarily about what would be good to teach children – what we wanted them to know, be able to do or understand. The examination system did not prioritise any political imperatives, such as employment prospects or an ability to contribute to the economic well-being of the country. Clearly, the examinations did provide employment opportunities and potential scientists and technicians for industry, but there was no explicit political driver for this. Callaghan viewed the state of the national examination as a contentious issue, something his 'new' Secretary of State for Education, Shirley Williams (b1930-), would be looking at carefully (see appendix H for a list of Prime Ministers and their Secretaries of State for Education from 1970-2018)

Callaghan's Ruskin Speech identified a need for more science teaching that would lead to students taking up technology related degrees, training and jobs saying, '*There seems to be a need for more technological bias in science teaching that will lead towards practical applications in industry rather than towards academic studies.*' (Callaghan, 1976, cited online by Gillard, 2010) He stated that a high proportion of girls abandon science and 30,000 places for science and engineering remained unfilled in Universities and Polytechnics at that point. Callaghan was making a political case for a NC related to economic prosperity and reducing unemployment. Although unemployment in the early 1970s was relatively low (by today's standards), at about 1 million people, it had steadily been increasing and would hit 1.5 million by the late 1970s. This was three times the rate

of a decade earlier (Leaker, 2009). With the discovery of North Sea oil in the 1970s, the need for scientists, engineers and technologists grew.

There was a clear political will to exert control over and influence core aspects of the education system. From the curriculum to the examination system, major changes were being signalled as being necessary with political priorities driving the changes. Greater accountability to Government, rather than the LEAs or parents was being proposed, with a revised and more powerful inspectorate proposed as the mechanism for accountability. Following on from this speech, several reports and discussion papers were produced that, in the way the 'Yellow Book' set out a reality or truth about what was happening in education nationally, would delve much deeper.

## **5.2 The 'red books'**

In 1977, HMI produced a series of working papers as a contribution to the debate on a common core curriculum. The following analysis considers those sections of the reports that reference science within the curriculum.

### **5.2.1 The first 'red book': curriculum 11-16**

The first 'Red Book' report (HMI, 1977) considered the 'core curriculum' as outlined in Callaghan's Ruskin Speech. The papers were intended to be discussed by HMI, LEA advisers and teachers. The reports were not, it was cautioned, to be seen as a blueprint for the Government's intentions. Having set out a case for a core curriculum, which included discussion of acceptable and unacceptable variation in curriculum provision across the country, 'current practice' was reviewed and various options discussed.

At the centre of the discussions was the vision of HMI that, *'(W)e see the curriculum to be concerned with introducing pupils during the period of compulsory schooling to certain essential 'areas of experience''* (HMI, 1977, p.6). One of these areas was 'The Scientific'. This is a view of science as a homogenous subject area. The Red Book did discuss the 'components of science' which went beyond the three traditional science subjects and encompassed a range of other disciplines though there is a clear implication that science was still this homogenous subject. For example when discussing what the various subjects had in common, the report said:

In principle, although not by any means necessarily so in practice, there is a widespread agreement on this; they are about matter in its various forms and they are essentially observational and experimental studies. Any scientific subject can have three components, namely, science for the inquiring mind, science for action and science for citizenship. (HMI, 1977, p.27)



The section of the report considering science assumes that 'the scientific' is understood. It creates a false impression of a coherent view of the different scientific disciplines that would be understood by teachers, advisers and others.

The report contained a statement from the science subject committee (made up of inspectors of science within HMI) which indicates a tension between the utilitarian view of science (as discussed previously), as a subject that delivered factual knowledge and skills in science, and an understanding of the NoS (in part) through the development of critical thinking skills:

Courses which are overburdened with content do not allow the pupils sufficient time to think, and knowledge is only as good as the use which is made of it. On the other hand, some content is essential to provide the vehicle through which scientific thinking can be developed, and there are important scientific ideas which every educated citizen should have met (HMI, 1977, p.27).

The science subject committee listed various criteria (HMI, 1977 p.25) for how science should be presented within a curriculum which can be summarised as follows:

1. Observational skills
2. Ability to recognise relevant observations
3. Pattern recognition
4. Pattern explanation
5. Practical skills
6. Ability to devise 'experiments' to test pattern explanations
7. Verbal and mathematical skills
8. Application of prior knowledge to new situations

Within these eight criteria, the idea of science as a subject through which 'thinking skills' could be taught is particularly part of the application of prior knowledge. The curriculum structure includes practical skills as well as thinking skills and ways of thinking scientifically. There is still a utilitarian approach that could be biased towards the political imperative of meeting the need to train children to 'do' science rather than an understanding of what science 'is' through the NoS.

The report does unpack 'the scientific' to discuss the main disciplines of biology, chemistry and physics and tries to bring them together to explain what 'binds' them as scientific subjects, as shown in the quote at the bottom of p.102. Once again, the emphasis is primarily on observational and experimental skills, followed by 'the inquiring mind'. There is also a section of the report that specifies the content of a common core science curriculum.

While there is a list of key words that should be understood (e.g. atom; gas; reaction; photosynthesis; diffusion; force etc.), interestingly this omits any key words related to the

NoS such a theory, hypothesis, law, principle etc. though the science inspectors acknowledge that the list is incomplete.

The report clearly sets out a science curriculum based in content (concepts) and skills (practical and observational). It entrenches the vision of science as a practical, laboratory-based subject. The NoS is notably absent in any coherent form.

### **5.2.2 Curriculum 11-16: a review of progress and towards a statement of entitlement**

The second 'Red Book' published in 1981, *Curriculum 11-16: a review of progress*, reported on a study of, '41 schools in five local authorities (that) worked with a group of HMI and advisers from the LEAs to re-examine their thinking about the curriculum.' (HMI, 1981, p.vii). 'Red Book' three, *Curriculum 11-16 a statement of entitlement*, developed a consensus on curriculum entitlement. Within this review of evidence from LEA advisers, teachers and others, key questions were asked which would have implications for the impending 'core curriculum' in the form of the NC. One was, 'if the aim is a worthwhile scientific experience for all pupils in a common curriculum to 16, are separate courses in three sciences the most appropriate way to achieve this?' (HMI, 1983, p.51). There was, perhaps, a recognition that the separate sciences were not delivering a coherent framework for a good understanding of 'the sciences'. Alternatively, it could be seen as indicating that general or integrated science was not doing the job of improving uptake post-16. This tension would be evident not just with the first SNC, which abandoned 'the three sciences' but also with those who, politically, wanted a return to 'traditional' teaching that delivered discrete subjects over 'integrated' disciplines in what Ball (1995, p.87) has described as 'cultural restorationism'.

Later, the report detailed how some teachers and advisers in LEAs had started to map and define the skills that needed to be taught in each of the five years of secondary schooling. A considerable amount of effort had gone into preparing for the new common/core curriculum, the precursor to the NC.

The overriding concerns of the 'Red Books' were educational and organisational rather than political. What the curriculum should contain, how it should be enacted and who it should be aimed at (entitlement) were the main concerns.

### **5.2.3 HMI 'matters for discussion'**

Between 1977 and 1982 – when the 'Red Books' were being compiled and published – a series of discussion documents were produced by HMI. These 'Matters for Discussion' had two that related to science education. A general document, *A view of the Curriculum*

(HMI, 1980a) and one that addressed *Girls in Science* (HMI, 1980b), a problem noted in Callaghan's Ruskin Speech.

In Discussion Matters booklet number 11, the issue of 'The Curriculum' was addressed. It noted a tension between common and individual needs when it comes to planning a core or common curriculum:

'The curriculum' has to satisfy two seemingly contrary requirements. On the one hand it has to reflect the broad aims of education which hold good for all children, whatever their capacities and whatever schools they attend. On the other hand it has to allow for differences in the abilities and other characteristics of children, even of the same age. Within the broadly defined common curriculum individual curricular programmes have to be built up year by year as children progress through school. (HMI, 1980a, p.1)

The booklet warned about the limitations of the curriculum that could be on offer to all children, something Huxley stated in 1899, as noted in Chapter 2:

Children cannot be forearmed with everything they may need to know or be able to do as adults, even if they were all ready to receive it. There must always be some selection. There are limits of resources, both generally and in individual schools. Some desirable developments, for example, depend on the availability of specialist teachers still in short supply, or as in the recent history of science, modern languages or technology, on the capacity of existing teachers to exercise new or different skills. (HMI, 1980a p.5)

There is a clear ideological steer here. The curriculum had to satisfy the idea of equality in education; it must be accessible to all. There is also a clear problem with the supply of specialist teachers and, in addition, limits to the general resources made available for subjects. In primary science, it was noted there was too little observational and experimental work done prior to children moving to the secondary school. The booklet ended with a series of propositions. Proposition 8 concerned the provision of science and it is suggested here that:

In any future development of the curriculum, to those elements already widely held in common - English, mathematics, religious education, physical education - should certainly be added some continued form of science education for all pupils. Whether or not it is presented under the traditional separate science subjects - and the individual school will have to decide on this in light of its circumstances - it should be of a sufficiently broad kind to familiarise all pupils, at levels within their understanding, with important concepts and knowledge which may both stimulate their minds and their imagination and equip them better for their future responsibilities as citizens. School science is one of a group of subjects, including mathematics and craft design and technology, which clearly have an important part to play in developing understanding and appreciation of technology. Engagement with the processes of science should

also be helping to strengthen general powers of observation and reasoning.  
(HMI, 1980a, p.16)

The important points to note in this proposition are that science should be a core subject for all and that it should be broad (whether as a general subject, or as separate subjects). Crucially, as noted in the quoted extract above, it should be helping to '*strengthen general powers of observation and reasoning*'. This is part of the 'processes' of science and, as such, it links aspects of the NoS with the skills of science. This was a subtle shift towards the 'thinking' aspects of science with a reference to 'reasoning'.

The HMI booklet dealing with *Girls and Science* (HMI, 1980b) began with a snapshot statistic of the average number of science subjects taken by girls vs boys: 0.82 v 1.28. The report resulted from a specific investigation of the issue of 'girls in science' that centred on 15 schools, deliberately chosen to cover as wide a range of geographical and social catchment areas as possible. The conclusions from this investigation (HMI, 1980b, p.29) were that:

the reasons for girls' choice of science subjects (or avoidance of them) at school are complex. The low uptake of the physical sciences in school is a long-standing problem not amenable to ready solutions.

In addition, they noted that the teaching of combined science in the first two years of secondary school with an undifferentiated curriculum for boys and girls helped increase confidence with the girls, but by the third year (currently year 9):

Girls were particularly affected by the premature introduction of abstract concepts and excessively mathematical approaches based on too little practical experience, often as a consequence of an undue emphasis on examination objectives.

In the fourth and fifth years (current years 10 and 11), the report also noted that:

Frequently the first term of the fourth-year course was too abstract, theoretical and mathematical, and pupils failed to see the purpose of their studies. The difficulties of the subject then dominated pupils' thoughts and their lack of confidence was apparent to third-year girls about to consider subject choices.

There is a contradiction here. On the one hand, HMI reported that abstract thinking is an issue that could be putting off girls choosing science, yet its curriculum document is advocating a curriculum designed to provide more reasoning skills in science, an abstract concept. There were assumptions made about girls and their capacity to engage in certain key skills such as abstract reasoning. This must be seen within the context of the

time and the stereotyping of girls and science that prevailed right up to the 1980s and beyond.

#### **5.2.4 The 1980 curriculum framework consultation**

In 1980 Mark Carlisle (1929-2005), then Secretary of State for Education, published a consultation proposal on a framework for the school curriculum (DES, 1980). This came from a DES circular from 1979 reviewing the curriculum across LEAs. The proposal was quite specific when it came to science in the school curriculum:

Science should form part of the experience of every pupil during the period of compulsory education. It should begin for all pupils in the primary school and continue to hold a place in every pupil's programme to the end of the period of compulsory education. In the early stages the emphasis should be on the processes of science and a broad course embracing elements of physics, chemistry and biology and their practical applications should continue until at least the age of 13. During the later years of compulsory education integrated science courses based on two or more of the specific science subjects may be appropriate, but the Secretaries of State consider that at this stage all pupils should normally devote at least 10 per cent of their school time to science subjects or closely related work, and that pupils should not normally devote more than 20 per cent of their school time to science subjects. (DES, 1980, p.6)

This was a specific consultation, which promulgated a vague 'double science' style option and stipulated a minimum and maximum amount of time. It emphasised the need for 'elements' of biology, chemistry and physics to be tackled from primary education to age 13 (at least), with an emphasis on the 'processes' of science, though the term is not defined. The clear implication here, from the political perspective, is that a form of 'general science' is what should be provided to the age of thirteen. At this point children would make a choice of which subjects to study for O level. One, or more, of the sciences could be dropped.

Following this consultation, in 1981 the DES published a booklet of advice on the school curriculum and a circular (DES Circular 6/81) that required LEAs to review the curriculum they have on offer in their schools. The advice booklet emphasised that science should be broad and balanced as children that drop one or more of the science disciplines at the age of 13/14 rarely, if ever, take up one of those disciplines at a later point. The advice also considered that science should be part of the curriculum for all abilities. At this point, there was no requirement for schools or LEAs to make science for all compulsory or indeed to provide a balanced curriculum. This was followed by another DES circular (DES Circular 8/83) that required LEAs to report on the progress and outcomes of their review of the curriculum required by the 1979 circular.

In 1981 the Schools Council, a body that from 1964–1984 was involved in the co-ordination of public examinations, also ran a number of curriculum projects, most notably for science the Schools Council Integrated Science Project (SCISP), which produced a booklet with advice and information on curriculum problems (Schools Council, 1981). The booklet set out a series of problems on curriculum development that needed to be considered:

- 1) Matching the curriculum and child development.
- 2) Identifying obstacles.
- 3) Organising the planning.
- 4) Talking about the curriculum.
- 5) Making a start.
- 6) Resources.

Over the period 1984-89, a further series of booklets, '*Curriculum Matters*' were published by HMI. The 1985 booklet *The Curriculum* (not to be confused with *Discussion Matters booklet number 11* as discussed earlier) had specific advice on what science 'is':

The scientific area of learning and experience is concerned with increasing pupils' knowledge and understanding of the natural world and the world as modified by human beings, and with developing skills and competencies associated with science as a process of enquiry. These include observing, selecting from the observations whatever is important, framing hypotheses, devising and conducting experiments, communicating in oral and symbolic forms and applying the knowledge and understanding gained to new situations. (HMI, 1985, pp.29-30)

The vision for science, set out here, is broad and contains a strong utilitarian view linked to skills and competencies and science as a 'process of enquiry'. It does not state what form such an enquiry (or enquiries) should take and it does not specify if this constitutes the structure or nature of science as a concept. It generalises all sciences and does not sufficiently consider that different disciplines will have different ways of working (or even that within a discipline there may be different ways of investigating/thinking). This is problematic. How different science disciplines come to conclusions, or how we can use different ways of thinking within a discipline, is not considered. In addition, the methods used by different disciplines will vary. To think of all sciences as homogenous disciplines or as a homogenous subject ignores these important differences.

In 1985 a DES Policy statement (DES, 1985) set out a vision for school science that was broad and balanced science for all. It sought to address the key issues that had been identified by the preceding reviews, surveys and analyses by HMI etc. that saw a deficiency in the teaching of, and approach to, science in schools and the need for all pupils up to the age of sixteen to study a broad and balanced science curriculum.

The Government, HMI and Government-related bodies had, over a period of ten years, committed considerable efforts into surveying and looking in detail at the curriculum generally and within that, science. This work was the bedrock on which the NC was built and delivered with the enactment of the 1988 ERA.

The analysis of the documents above broadly come within the educational theme for this thesis, it sets the scene with respect to what was happening across the 1970s and early 1980s from an educational perspective but includes references to the political tensions that initiated the reviews and reports. While HMI were concerned with what the curriculum content should be and how science should be delivered, one of the political imperatives was the uptake of the sciences at O level and beyond.

The decision to implement a NC was a political one. Such a move required legislation to be drawn up and enacted so that, for the first time, a curriculum and its content, common for all state schools, would be a legal requirement. Part Two discusses the political run up to the NC, which politicians were involved and what their motivations were according to their own accounts of the period.

### **5.3 Part Two: the political origins of the national curriculum**

Callaghan's 1976 Ruskin Speech is widely regarded as the start of a major debate on the nature and purpose of general (i.e. state maintained) education. In this speech, Callaghan articulated his view of the nature and purpose of education:

The goals of our education, from nursery school through to adult education, are clear enough. They are to equip children to the best of their ability for a lively, constructive, place in society, and also to fit them to do a job of work. (Callaghan, 1976, cited online by Gillard, 2010)

This is the clearest indication of a political ideology being applied to the purpose of education, that is, education is about being a productive member of society. Education was about our economic success and reducing unemployment. These, in effect were political goals that education should be working toward. In examining some of the areas of educational concern, Callaghan also identified '*...the strong case for the so-called 'core curriculum' of basic knowledge*' (Callaghan, 1976, cited in Gillard, 2010).

### **5.4 The politicians' views**

In this section, political autobiographies and biographies were analysed with respect to events leading up to and after the introduction of the national curriculum.

Following a general election in May 1979, there was a change of Government, and a Conservative Secretary of State, Mark Carlisle, was appointed under Margaret Thatcher

(1925-2013). Carlisle instigated major reforms, such as the establishment of a School Curriculum and Development Committee (SCDC) and the Secondary Examinations Council (SEC). This paved the way for a NC (House of Commons, 2009).

Thatcher, in her autobiography, wrote widely about education. She was of the opinion that, as a nation, we invested less in science and technology and that '*we educated and trained our people to a lower standard*' (Thatcher, 2011, p.5). Her view was that as a nation we were complacent over education. She was very critical of the previous periods of Labour control, a time she characterised as overt central control, with Labour having a '*finger in every pie*' of governance (Thatcher, 2011, p.5).

Thatcher believed the Conservatives were trusted by the public on education and was of the view that they would be trusted to deliver on academic and non-academic subjects, raise standards, provide parental choice and value for money in education. This contrasted with what she saw as the public's vision of labour as the '*loony left*' interested only in social engineering and sexual liberation (Thatcher, 2011, p.562). Thatcher appointed one of her most trusted friends and her political mentor, Keith Joseph (1918-1994), to the post of Secretary of State following a cabinet reshuffle in 1981.

Joseph's appointment was not universally welcome. The national newspaper for teachers, the *Times Educational Supplement* (TES), said it showed Thatcher had a '*low opinion*' of the Department for Education and Science (DES) (Denham, 2001, p.367), an opinion Thatcher developed during her time as Secretary of State for Education from 1970-1974. One thing she was prevented from doing by department officials in the early 1970s was withdrawing the previous Labour Government circulars requiring LEAs to prepare to convert all schools to comprehensive status. Thatcher also felt that the relationship between the DES, teachers and teacher unions was too comfortable (Denham, 2001, p.365).

#### **5.4.1 Joseph's turbulent times**

Joseph believed that 50% of children received no benefit from their 11 years of education, though in public pronouncements he was persuaded to reduce this to 40%. Joseph's view of the purpose of education was that it was to meet the employment needs of a free market economy and, in this, he believed we, as a nation, were failing (Denham, 2001).

This characterises a Conservative ideological view of education as a means of meeting the economic needs of the country. Conservative educational hegemony was not necessarily about personal development or intrinsic motivation. It was necessary to



service the country with a supply of employable people to deliver economic success. This stance fits the political theme developed within this thesis and exemplifies how politics has a strong influence on the structure and organisation of state education.

After the 1983 general election, a decisive victory for the Conservatives, Joseph was tasked to implement changes, promised since 1980, to public examinations at 16, the O level and CSE (Certificate of Secondary Education). He began the tricky task of looking at the implications of state interference in lessons, the so-called 'secret garden' of curriculum content. Joseph was laying the foundations for much of the NC to come, but after a disastrous May local election in 1986, and public disquiet over Joseph's tenure, Thatcher realised he was not the man to lead a major educational reform that would be the centrepiece of the Conservative's next general election manifesto. At this point, Joseph had decided to retire from politics. For much of his time he had been at odds with teachers and unions, usually about pay. At the point he was deciding to retire, HMI were about to publish a report claiming that 25% of schools were under-resourced and 30% of lessons were unsatisfactory (Denham, 2001). Joseph's successor, Kenneth Baker (b.1934-), was keen to take over from him and had familiarised himself with the issues and possible solutions to the education problem.

It was Baker, who took on, and was winning, the arguments against the 'loony left' Local Authorities, that persuaded Thatcher he was the right man for the education job (Thatcher, 2011). Baker had strong views about education including vocational and technical education, views that he still espouses today with his support for technical education from 14-19 (Anon, 2018a). Such views also fit the narrative of education as a means of servicing commerce and industry and for the economic well-being of the country.

#### **5.4.2 Baker and the birth of the national curriculum**

The Conservative Government had lost faith in the ability of LEAs to raise standards in schools. There was no coherence over what was taught from LEA to LEA, as revealed by the LEA curriculum reviews started in 1979. Many Labour LEAs were seen as dysfunctional by the Government.

Considering the political theme for this thesis, it is clear that the then Government felt a wholesale reform of state education was necessary. Structures that had been in place for 70 plus years were seen to be failing or had moved away from the political ideology that characterised Conservative views on education, such as selection by attainment.

Politically the NC was becoming an inevitability. Baker cites Callaghan's Ruskin Speech and Joseph's ideas as influences for his own conception of a NC (Baker, 1993). His plan was based on standards and choice via a NC, testing, new City Technology Colleges (CTCs) as well as Grant-Maintained (GM) schools.

When Baker took over as Secretary of State, morale at the DES was low, with teacher strikes and a lack of central funding all playing a part. One of his first actions was to request £75 million to fund textbooks and school building repairs. The request annoyed Thatcher, but he was given £20 million for the implementation of the new GCSE examinations (Baker, 1993). Baker saw education generally as having a progressive ethos, with the DES hand-in-hand with the unions (especially the National Union of Teachers). This resulted in him restricting access to the DES and its officials by union officers. His view was that when he took office education was anti-excellence, anti-selection and anti-market. HMI were also under criticism for not raising standards via inspection (Baker, 1993).

Baker set out to produce a curriculum that was accepted by teachers, the unions and others by agreement and consent. The DES officials wanted to concentrate on the syllabuses (specifications) at 16 and 18 years of age and the Treasury warned of the possibility of escalating costs as it predicted more teachers would be needed if more subjects became compulsory. These were clear political tensions.

Baker presented his first curriculum ideas to Margaret Thatcher on June 23<sup>rd</sup> 1986. This included 'attainment targets' that could be used to track progress, the first indication of the imposition of accountability by Government on schools. Thatcher was supportive, so Baker continued to develop his ideas. The following September he again raised the notion of a NC. He was particularly concerned with English, driven by frequent business and employer complaints that schools leavers were illiterate and data that showed over 6 million adults struggled with reading and writing (Baker, 1993, pp.189-191).

Baker took the unusual step of appointing a mathematician, Sir John Kingman, then Vice Chancellor of Bristol University, to develop and report on the English curriculum. His reasoning was that different factions involved in the academic study of English (the strict grammarians and the progressives who did not adhere to strict grammatical conventions) should not impose any one ideological position on a curriculum. The report (Kingman, 1988) concluded that there were different dialects and that no single correct version of English existed. The use of English was very dependent on context e.g. within specialist work, in the media, even within politics. The report presented was not the one Baker wanted.

This event is symptomatic of politics and the drive for answers that fit with the preconceptions of ministers. Baker clearly had in mind what he wanted the report to show, (perhaps that a traditional grammarian approach to English was best) and what should happen, but he was frustrated when the ‘correct’ answer was not forthcoming from an independent expert (Baker, 1993).

The first public announcement of a proposed NC was made on 7<sup>th</sup> December 1986 on the political television programme ‘*Weekend World*’. This was deliberate. Baker was keen to avoid internal wrangling over his proposals within the party. The public announcement made before being cleared internally by officials at Downing Street or in Parliament, stifled dissent. Thatcher, he claims, approved of this move (Baker, 1993). Baker’s view was that the quality of education across the country was a lottery. During the spring of 1987 he debated the detail (though not the content) of the curriculum structure with Thatcher. The details needed to be agreed by April 1987 due to a possible election in the summer. The election in June 1987 returned a 102-seat majority and a third successive term for Thatcher.

After the 1987 election, Thatcher had expressed misgivings over the standard of education being delivered. The teacher/pupil ratio had fallen, spending on education was up, but standards were not. The Inner London Education Authority (ILEA) epitomised everything Thatcher did not like about education; it was high spending but delivered some of the worst public examination results in the country. She was also against ‘*progressive*’ child-centred learning and preferred the learning of ‘*facts*’ within discrete subjects rather than skills gained in amorphous subject groupings like ‘*humanities*’ (Thatcher, 2011 p.590).

Thatcher had a view of what education should be. In the context of the educational theme for this thesis, she was promoting a traditional, knowledge-based, direct instruction pedagogical approach to teaching subjects. This is a clear example of Ball’s (1995, p.87) ‘*cultural restorationism*’. Thatcher’s view contrasted with the direction science education was taking. Integrated science with a strong relationship to social context was being advocated, principally by the Association for Science Education (ASE). It led one of the architects of the integrated science policy, Dick West, to remark that the reaction to such a curriculum was leading to, ‘*a very bloody battle between the three subject club (physics chemistry and biology) and the so-called integrationists (science is science)*’ (Jenkins, 2019, p.161). Thatcher had misgivings about blocking together subjects under a ‘humanities’ label, yet she was silent over how the sciences were delivered, particularly the common deployment in the state sector of science teachers as science generalists

– being asked to teach up to five separate disciplines – regardless of their own subject specialism.

A curriculum alone, for Baker, was insufficient to improve educational standards. He determined that there needed to be a measure of progress built into the curriculum with tests at regular intervals. His initial idea was not for summative tests but diagnostic ones that determined for teachers the help individual children needed. The major teachers' union, the NUT, rejected the idea of a NC and regular testing (Baker, 1993). As the plans progressed, the diagnostic tests would be seen as a key tool for school and teacher accountability by Baker.

#### **5.4.3 The establishment of subject working groups**

In April 1987, mathematics and science working groups were set up to begin the process of adding specific content to Baker's framework for the NC. A central plank of the Government's next political manifesto would be the establishment of the NC. This was a bid to revolutionise and raise the standard of education nationally, along with the establishment of a new type of school. These were GM schools that were free from Local Authority control.

Thatcher acknowledged that one option for education was more centralization, even though this ran counter to the Conservative mantra of decentralisation and market forces. She felt that core subjects such as English, mathematics and science needed more consistency and one way to achieve this was through centralisation. She declared openly that she *'never believed...that the state should try to regiment every detail of what happened in schools'* (Thatcher, 2011, p.591).

Thatcher's vision of the NC was for a reasonably small core (developed by teachers) that concentrated on a small body of knowledge with room to expand on this according to the children's interests and the school's ethos. Tests, which she agreed with, would only be a *'snapshot'* of either a child, class or school and were, at best, simply a check. Testing, according to Thatcher was not about measuring the merit of a child, teacher or school, but a way of knowing what children *'understood'* (Thatcher, 2011, p.593).

Thatcher clearly supported a degree of centralisation, which falls within the political theme, but within the organisational theme she preferred that to be on a large structural scale, rather than trying to micro-manage the organisation of schools. Thinking about the educational theme, it is clear that Thatcher saw the 'tests' as more diagnostic for teacher use than being used for accountability.

Baker, however, had a different and bolder plan for the NC. Nearly all subjects would be covered and be compulsory. In an audacious move, he threatened to resign from his post if Thatcher did not allow him to implement his plans in full. Given the fact that the central manifesto pledge was the 1988 ERA which would revolutionise education by removing many LEA controls, giving financial independence to headteachers to raise educational standards, Thatcher had no option but to capitulate (Baker, 1993).

This insight into the workings of policy at Ministerial level is interesting. A national policy, devised by one Minister, albeit with input from various others, is enforced using the threat of disruption to his own party's election hopes. One argument being supported in this thesis is that politically driven curriculum change is not effective when politicians, who are neither experts in the curriculum nor in education, can exert undue pressure to force through change against the wishes and opinion of experts and end users.

The Conservatives won the 1987 election and, as a result, the 1988 ERA came into effect. GM schools were established as was the Local Management of Schools (LMS) giving more independence from LEA control and direct financial management for headteachers.

Baker moved quickly to implement his plans. He wanted mathematics and science in place by 1989 and English in 1990. To facilitate this, he set up the National Curriculum Council (NCC) and the Schools Examination and Assessment Council (SEAC). Despite intense opposition from teachers, unions and academics in education, Baker also insisted on a test regime with results to be published in the form of 'league tables'. The argument against such a move was that it would not take into account any data on the social background of the children, so making meaningful results very difficult to obtain. This argument was initially ignored, though contextual data were added and used in later league tables.

SEAC proposed Standardised Assessment Tasks (known as SATs), but Baker (1993) doubted they would work. He wanted pen and paper type tests rather than assessments carried out by teachers. Regardless, SEAC set up and developed the SATs with education academics at King's College London. These were predicated on teacher assessment of pupil progress and understanding. In science, it was a mix of practical and pen and paper assessments, though not high-stakes externally set tests.

In July 1989 Baker was replaced by John Macgregor (b.1937-). Macgregor was tasked with ensuring the various NC working groups delivered proposals that were workable. There were many issues with the first draft version of the SNC (see Chapter 6). Various

versions of the other NC subjects seen by Thatcher dismayed her. For example, in history she saw no sense of any chronology for major events in British history (Thatcher, 2011).

Thatcher felt that the various subject orders were lacking in basics and overly complex. On the science curriculum she was not happy with the topic approach, feeling that the distinctive subjects of biology, chemistry and physics were lost. This was one of the few times she expressed a desire for separate sciences over 'the sciences'. The NC was failing. There were many challenges and complaints about the structure and content of various curriculum documents. Thatcher (2011, p.597) placed the blame on Baker saying that he, '*...paid too much attention to the DES, HMI and progressive educational theorists in his appointments and early decisions*'. Despite the curriculum being a political invention, it was the education community that was blamed by the politicians for any failings.

Macgregor had difficulties dealing with various factions (teachers/science education advisers/academics/unions) fighting for control over the science curriculum. In science, a dual model had been proposed that saw most children take a double science award (the equivalent of two GCSEs) known as Model A. Model B allowed for children to take the equivalent of one GCSE. Both models included content from the three main science disciplines. A third, but not a formal model, allowed children to take the separate sciences. For this to succeed Macgregor proposed to make some subjects non-compulsory, such as art and music (going back on an announcement he made in 1989 that all subjects would be compulsory) to allow children to take more important subjects (in his view and clearly in Thatcher's view), such as separate sciences. The changes were driven by teachers in schools, many of whom expressed concern that double science would leave children unprepared for A level separate sciences (Anonymous, 1990).

Private schools maintained their commitment to delivering separate sciences with subject specialists. In many state schools there were media reports documenting issues in attracting specialists to teach some of the science disciplines, such as physics (Crequer, 1989; Maclure, 1989; Weston, 1989). By November 1990, Macgregor had been replaced by Kenneth Clarke (b.1940).

#### **5.4.4 The Clarke era**

Clarke did not want the post as Secretary of State for Education and he suggested William Waldegrave (b.1946) as a potential post holder. Thatcher objected on the grounds that Waldegrave was an Etonian, a rejection based on her view that his

experiences and background would not resonate with teachers and the unions (McSmith, 1994).

Clarke's main job was to clean up the legislation put in place by Baker and deal with issues raised by teachers and the unions after mathematics and science became statutory. The full NC specified 10 separate subjects for all pupils to study. Clarke thought this was too inflexible and agreed, under pressure from teachers, to stipulate that only English, maths and science should be compulsory. What also worried the teachers and unions was that the NC not only specified what content to teach, it had many references as to how to teach each subject. Clarke's response to this was that he felt teachers cared more about how things were taught than what was taught. He branded them the '*enemies of high standards*' (McSmith, 1994, p.188). This was a clear political preference for a traditional direct instruction pedagogy transmitting facts and knowledge over what Clarke perceived to be a child-centred progressive pedagogy, another piece of evidence for Ball's (1995, p.87) '*cultural restorationism*'.

This was the first time that politicians had not only entered the 'secret garden' of the subject content to be taught but had also acted as the 'head gardener' by imposing directions on how subjects should be taught – something that, to this point, had been the preserve of the individual teacher. Politics had begun to influence not just the organisation of schools and education, it was staking a claim in the educational realm of what should be taught and, more importantly, how it should be taught.

Within weeks of Clarke's appointment, John Major (b.1943-) replaced Thatcher as leader of the Conservative party and as Prime Minister. This heralded a new era of Conservative politics. Clarke remained in office for two more years and oversaw many changes to the relatively new NC. He revised and changed the terms of teachers' pay and contracts with a new pay review body and gave himself and future Secretaries of State extensive new powers - more centralisation. He pursued the idea of choice with a 'Parents' Charter' and established a new Office for Standards in Education (OFSTED) appointing Chris Woodhead (1945-2015) as the first Chief Inspector. OFSTED became the effective agent for accountability.

During my time as a science teacher in the late 1980s early 90s I was involved in piloting and testing the key stage 3 'tasks' being developed by King's College. They were cumbersome and far too difficult to implement easily. They took away teaching time at Key Stage 3, which impeded the delivery of the SNC content. When Kenneth Clarke took over as Secretary of State for Education in 1990, he visited King's College to see how the tasks were progressing. He called them '*complicated nonsense*' (Black, 1995a,

p.174). They were scrapped in favour of externally set tests whose results were to be used for school and teacher accountability and reported to parents, ultimately being used in league tables of results for whole school accountability.

#### **5.4.5 Patten and Shephard: review, selection and specialisation**

Under Major, education remained as a key political focus. Following his first election as leader in 1992 Major replaced Clarke with John Patten (b.1945). In 1993 Patten asked Ron Dearing (1930–2009) to conduct a comprehensive review of the NC. There had been many problems with its implementation, with tensions arising over the different influences, as noted previously. There were several reviews of the statutory orders and content. This led to teachers becoming increasingly annoyed by constant change (Abrams, 1994).

In a cabinet reshuffle in 1994, Patten was replaced by Gillian Shephard (b.1940) a former teacher and inspector of education from Norfolk. In 1994 Shephard received the Dearing Review. Key outcomes from this review recommended that the content be reduced, the curriculum made less complex and that once these changes had been made, there should be no more change for at least five years (Dearing, 1994).

Major fought the 1997 election on 'traditional values' and 'back to basics', yet more evidence for Ball's (1995, p.87) '*cultural restorationism*'. There was, for education, the promise of more selection in schools and the return of grammar schools. The election was lost. A new political era was entered when Tony Blair (b.1953) led New Labour to a landslide victory in the 1997 general election.

#### **5.4.6 Blair's views on education**

Blair's concern with Conservative education policy rested on the drivers for change (Blair, 2011). The reforms the Conservatives had made were linked to school performance and the satisfaction of parents. The actual service users, the children, had no say. The parents were the 'proxy' service users. Blair believed that as a country we accepted failure and underachievement far too readily and children were not challenged enough. He was not anti-selection and felt that we could learn from how selective schools operated and how they were run, without necessarily creating more of the same. He felt that the Conservatives had only partially tackled the education issue.

Blair had to remove GM status for schools, as this was a New Labour manifesto commitment. He was keen to change poorly performing schools rather than do what the Conservatives had done which was allow the successful to change to GM status, the Conservative's attempt to apply 'market forces' to state education, leaving the poorer



schools to fail as parents rejected them for their children. He embarked on a radical structural change, his academies programme, to solve the poorly performing school issue (Blair, 2011). This was also a political influence, but a different ideological one from Conservatism.

The political influences on schools were intense during this period. The Conservatives paved the way for more centralisation and New Labour continued this move and used powers inherited from their predecessors to impose their political ideology on state education. Organisationally in education there were many challenges ahead, e.g. the number of different types of schools proliferated creating confusion over their status.

Blair appointed David Blunkett (b.1947) as his Secretary of State for Education and Employment and many of the Conservative reforms from the 1988 ERA were kept in place. An idea of Patten, specialisation linked to a form of selection, was taken up as Blunkett proposed setting up specialist schools that could select a percentage of their intake by aptitude. This avoided the return of the '*Grammar School debate*' and sidestepped the selection issue (Smithers, 2008, pp.361-362). This marks a turning point for comprehensive education. No longer was universal comprehensive education the political road along which education travelled. Specialisation with selection and structural change now became the norm. Blunkett encouraged mixed ability teaching, but not universally. In mathematics and science setting was encouraged centrally (Chitty, 2009).

Encouraging setting in science had the effect of reinforcing the 'three sciences' as suitable for high ability pupils rather than the broad, balanced science for all promoted in the mid-1980s. This is one indication of a lack of coherence within science as a subject in schools. In Key Stage 3, integrated/combined science was common which could lead to a view that the sciences were homogenous. But at Key Stage 4, Model A and B promoted 'double science' (often taught and examined as 'separate sciences') or, for the more able 'the separate sciences'. This could lead to the view of different sciences being specialist individual subjects, not dependent on other sciences. With no coherent teaching on the NoS or the methods different sciences use the idea of science as a holistic subject with an underlying structure was missing.

New Labour maintained the NC and respected the Dearing review with its moratorium on change. They did have issues with the low standard of numeracy and literacy achieved by children. To tackle this, they implemented a 'National Strategy'. Over time this covered all the NC subjects.

Not only was the content of the NC subjects specified, how the content was to be taught was subject now to statutory legislation – a step further than the Conservatives who gave examples of ‘how’, but never enforced a particular way of teaching the specified content. Labour became the effective ‘head gardener’ of the secret garden telling teachers what teaching methods to use (e.g. via the National Strategy documents for subjects) and how these should be deployed in fulfilling the NC.

In 2001 Blunkett was promoted to Home Secretary and Estelle Morris (b.1952), a former PE and humanities teacher, was given the Secretary of State for Education and Skills post. She only served for one year and resigned, stating that she felt she had not ‘...*been as effective as I should be*’ (Anon, 2002). Over the next four years there were three more Secretaries of State for Education (see appendix H).

By 2007, Blair had been Prime Minister for 10 years. At this point he stepped down and Gordon Brown took over as the party leader and Prime Minister. This final period of office for New Labour was characterised by a further expansion of the academies programme. During this period there were three important, wide ranging curriculum reviews. An ‘Independent Review of the Primary Curriculum’ (IRPC), conducted by Sir Jim Rose, published its findings in April 2009; the Cambridge Primary Review, also published in 2009 and a House of Commons Children, Schools and Families Committee (CSFC) report on the NC, was published in April 2009.

## **5.5 Summary**

In answering the questions Posner (2004) asks within the second set of his framework for the analysis of a curriculum, ‘*to what social, economic, political, or educational problem was the curriculum attempting to respond?*’, it is clear that in the run up to the implementation of the SNC the following were pertinent.

### **5.5.1 Accountability problems**

Politically it was felt that schools and teachers needed to be held accountable. This was evident in Callaghan’s Ruskin speech and his concerns, echoed by Thatcher’s government, on the role of HMI in holding schools to account. Schools had been operating in isolation from central Government, answerable only to LEAs with respect to standards and outcomes. Keith Joseph and Margaret Thatcher were keen to remove many powers that the Local Authorities had. The introduction of tests at ages 7, 11 and 14 was one way of ensuring accountability at the school level. At the same time, there was a move to side-line the LEAs stripping them of many of their powers, as well as funding, and giving more control over school budgets to headteachers under the LMS initiative. It was dressed up as ‘autonomy’ for schools and headteachers, but the reality

was more centralised control, especially in the form of what subjects were taught and, ultimately, how they were taught.

To achieve the goal of greater curriculum accountability, the NC was proposed. This would mean that a common core set of subjects and content could more easily be used to compare schools, even individual teachers. Politicians were interested in ensuring that there was a supply of adequately educated and qualified young people that could usefully enter the jobs market. Employers had complained about levels of literacy, so Government resolved to do something about this situation.

### **5.5.2 Social problems**

The change to a comprehensive education in 1965 meant that the entitlement to a curriculum was extended to all children and that any school curriculum needed to satisfy the needs of all children. Unlike the first half of the century, where the curriculum was about delivering a training and access to university level science education, through the private schools and, to a lesser extent, via the grammar schools, the comprehensive system gave similar opportunities for a far wider proportion of the population. Even in the 1950s and early-60s, the era of tripartite education, the organisation of schools followed the social class system. Access to the academic subjects was controlled through a selective education system. Social mobility was an issue that the Conservatives felt would only be addressed through a selective education system (a similar situation exists today). Labour was opposed to selection and felt social mobility should be addressed through equality of access to education. Changes to the structure of schools, admissions policies and the examination system clearly favoured the equality of access route at first. Later changes to school admissions, such as parental choice and specialisation opened a 'back-door' to the secret garden through which social mobility could be achieved via selection.

### **5.5.3 Economic problems**

Thatcher's priority as Prime Minister was to reduce inflation and unemployment figures. During the 1970s inflation had risen to 25% and unemployment was also rising, hitting an all-time high of over 3 million by the mid-1980s. Thatcher was elected after the notorious 'winter of discontent' in 1978-79. That period saw power cuts nationally and many strikes, with demands for higher pay from many public-sector workers. This included teachers.

The mid 1980s was a period of unrest for teachers. Far from the teaching unions being unified forces acting for teachers and their pay dispute, they were divided. From 1984-86 there were work-to-rule actions, resulting in a loss of teachers' goodwill running sports

teams and clubs. From the Thatcher Government came more centralisation and control over teachers. For example, the independent Burnham Committee, which had dealt with teachers' pay and conditions, was scrapped and the Secretary of State was now in control of pay and conditions.

The imposition of a NC was a political one partly in response to economic factors. The curriculum was designed to ensure that schools produced children with the knowledge and skills to enter the world of work and contribute to the economic success of the country. In particular, there was a political need to try and improve the uptake of sciences post 16 and to ensure a supply of scientists, engineers and technologists.

#### **5.5.4 Political problems**

With the formation of a new Conservative Government in 1979, there was a move to radically change the educational scene to remove powers from the LEAs, which had been identified as ineffective. Too many LEAs were Labour controlled in Conservative opinion. In Thatcher and Baker's view, they were promoting progressive child-centred education. The Conservatives thought this was also the case within ITT. The move to impose a NC was a way of solving the political problem of a Government that, even when in power, was powerless to act and prevent an opposing party that held local power from imposing its own party-political ideology on education. The Conservatives favoured a traditional direct instruction pedagogy and a more traditional view of the curriculum as knowledge-based subjects where the teaching of facts (e.g. in science) or chronology (in history) and grammar (in English) took precedence over child-centred, discovery-based learning.

#### **5.5.5 Educational problems**

Educationally, it had been known for some time that the provision of subjects and the content of subjects (even the same subject) could vary greatly depending on which LEA or which region of the country a child attended a school. There were issues over the take up of science post 16 as well as girls considering science as an option. When there was greater choice for children in which O level or CSE subjects they took at 16, the numbers taking all three sciences were not consistent. Boys dominated physical sciences and girls, biological sciences. There was evidence that examination outcomes for the girls were not lower in the physical sciences than for boys. From the 1950s to the late 1970s there were several science projects that delivered combined, integrated, even modular courses for lower secondary school science. Primary science was poorly delivered, if at all, in any meaningful sense, until the implementation of the SNC.

**5.5.6 A curriculum of consensus: a solution to the problems?**

Educationally, Baker wanted a curriculum by consensus. To this end, the working group took evidence from a wide range of stakeholders. Chapters 6, 7 and 8 analyse the various versions of the science curriculum to show its evolution and development over time, particularly in respect of the NoS and the problems that arose from a curriculum by consensus.

## Chapter 6

### Analysing the Nature of Science in the Science National Curriculum

This chapter, along with Chapters 7 and 8, analyse the SNCs with specific reference to the NoS. The three chapters taken together analyse how the NoS changed and developed between 1987 and 2010 across eight different versions of the curriculum. In each, the NoS is present, but its prominence and impact with respect to the purpose and content of the curriculum changes dramatically. This chapter concentrates on the first draft version of the SNC (DES, 1988b) as this contains the most explicit and comprehensive view of the NoS.

This thesis, so far, has explored science education, from the 19<sup>th</sup> Century through to the mid-1980s, investigating the educational and political ideologies that influenced and led to the NC as well as some structural influences. As the historical analyses revealed (see Chapters 2 and 5), the NoS did not feature as an important aspect of science education. As has been shown, some features of the NoS did appear, such as ‘scientific thinking’, but none of the reports analysed in Chapters 2 and 5 set out what could be called a coherent, consistent view of the NoS.

The educational purpose of the curriculum was firmly fixed on science as a utilitarian subject from its earliest days (Chapter 2) and the content was linked to that purpose (e.g. teaching how the blast furnace works in chemistry featured in many courses and textbooks – this was at a time when the steel industry in the UK was a dominant one). Many of the science courses and examination syllabuses used in schools during this period were focused on imparting a basic knowledge of scientific concepts and a training in science skills designed to prepare children for further or higher-level instruction in science leading to jobs as science technicians, scientists, engineers or technologists.

A major problem in education was that the provision of science was highly variable across the country. Boys dominated in the physical sciences (as evidenced in Chapter 2). Politicians recognised this as an issue with respect to our economic prosperity and international standing. Thirteen years after Callaghan’s Ruskin Speech in 1976 and his case for a common core curriculum, it came into effect.

The argument being constructed through the analyses in this and the following two chapters is that the science curriculum lacked coherence and presented a flawed view

of science. It did not provide any structural understanding of what science is from an epistemological perspective. I further argue that a political hegemony took precedence over an educational consideration with politicians seeking greater dominance of and accountability from schools and teachers.

The first political imperative was a need for trained scientists who had the skills to undertake roles that supported our economic interests. Any educational purpose related to scientific literacy or public understanding of science that required an understanding of the NoS, was less important and took a secondary role (see Chapter 3).

A second political imperative was the desire to hold schools and teachers more accountable for what was delivered, as well as the progress made by children throughout their education. Accountability was to be measured by new tests at age seven, eleven and fourteen and new public examinations at age sixteen (see Chapter 5).

The political ideology of 'what should be taught and how' was driven by what Ball (1995 p.87) has described as '*cultural restorationism*'. This is an attempt to revive some imagined 'golden age' of education. Thatcher and Baker were fans of 'traditional' subjects and the teaching of facts and chronologies. Baker, however wanted a curriculum of consensus. His plan for deciding the content of the various subjects was to convene subject groups. In 1987 he established the Science Working Group (SWG) that produced the first consultation document for the introduction of the SNC in 1988.

### **6.1 The purposes and content of the curriculum**

As described in Chapter 5, the Department for Education and Science and the Welsh Office (DES/WO) published a proposal for consultation on *A Framework for the School Curriculum* (DES, 1980). In 1981 a follow up publication noted that the school curriculum should not be static, '*but must respond to the changing demands made by the world outside the school*' (DES, 1981, p.1). The document proposed that all primary aged children should be taught theoretical and practical science:

Primary schools should provide more effective science teaching. Children should be given more opportunities for work which progressively develops their knowledge; it is equally important to introduce them to the skills and processes of science, including observation, experiment and prediction. Considerable efforts have been made over the past few years to stimulate and support science teaching in primary schools, and these efforts have been intensified following the recommendations in HM Inspectors' survey of primary education in England. But more is needed: many primary schools could make more effective use than they do of those teachers who have some specialist knowledge of science. (DES, 1981, pp.11-12)

What is clear from this statement is that skills and processes, combined with examining knowledge, is the focus. The NoS is not considered or made explicit here. The purpose of science according to this document was a utilitarian one. A key outcome was to engage children in the study of sciences and to prepare them for further and higher study in science. The educational goal is aligning with the political to ensure a supply of scientists and to deliver training in how to do science. Maintaining a steady supply of scientists and technologists was essential for the economic well-being of the country and would be helpful in maintaining our position internationally as a leading science and technology nation.

In setting out the trajectory for science within schools in England and Wales, the DES/WO was intent on tackling the lack of uptake in the sciences after the age of 13. This led to a consultation document on '*Science Education in Schools*' (DES, 1982). In 1985 these proposals were turned into a statement of policy on the provision of science for all children aged 5-16 (DES, 1985). The focus was a process and skills model of science rather than encompassing an understanding of the epistemology of science as an academic discipline. What type of scientific reasoning (induction, deduction, abduction), a fundamental component of the NoS, should be used is lacking, or is assumed.

It was against this background that a Science Working Group (SWG) was set up to produce a SNC for ages 5-16. Neither the school curriculum proposals, nor the statement of policy were explicit about the inclusion of the NoS. The policy direction was for the provision of an improved science education that:

allows the highest existing standards of science education to be maintained; caters fully for pupils who will be unable to reach those standards; and gives genuinely equal curricular opportunities in science to boys and girls. (DES, 1985, p.1)

The educational and political imperative is clear; science uptake was being targeted, initially at post 13, but ultimately at post 16. The science working group was set up by Baker and Peter Walker (Secretary of State for Wales). The responsibility for the construction of the curriculum was placed in the hands of science education experts rather than experts in science disciplines from universities. The job of the SWG was to develop the content and means of assessment for the curriculum to be delivered by secondary science teachers and primary teachers. What was new and, to an extent, revolutionary, was the framework for the structure of the curriculum which consisted of



'Statements of Attainment' and 'Programmes of Study'. Those working in the SWG initially had no idea what these were or what they would look like (Donnelly, 2001).

## **6.2 How the curriculum was organized and underlying assumptions**

The group was set up in July 1987 and reported on 30<sup>th</sup> June 1988. This was a very short timescale for such a major project. The group comprised members who represented several education and business sectors. Interestingly the SWG did not contain scientists from university science departments. The terms of reference set for the SWG (DES, 1988, p.109) defined Attainment Targets (ATs) as:

clear objectives for the knowledge, skills and understanding and aptitudes which pupils of different abilities and maturity should be expected to have acquired at or near certain ages.

The Programme of Study (PoS) was defined as:

Describing the essential content which needs to be covered to enable pupils to reach or surpass the attainment targets.

To inform their work, the SWG took informal advice, written submissions of evidence and commissioned work from a wide range of individuals and bodies (DES, 1988b, p.1). In total 164 organisations/bodies submitted oral evidence. Individual submissions were received from 92 people and the group further commissioned work from eight organisations and 23 other individuals. It was an extensive trawl for evidence on what was to be included in a defining curriculum.

One issue that arises is the sheer volume of evidence gathered from such a wide array of possible stakeholders. This would make satisfying all these parties to create a curriculum of consensus very difficult. There was a danger, from the outset, that the curriculum could be too cumbersome to be effective, or the content so watered down it satisfied few of those consulted. The structure and organization of the curriculum was pre-determined. It was assumed that all the subject curriculum documents would follow the same structure. Whatever content was chosen needed to fit this pre-determined structure.

## **6.3 Science for ages 5-16: the initial proposal/consultation**

In August 1988, in time for the start of the new school year, a consultation document was sent to all schools in England and Wales (DES, 1988b). This contained a summary of the work of the SWG and the core knowledge, understanding and means of assessment being proposed for the new NC in Science. Chapter two of the proposal set out the SWG

view of science and technology, it was the SWG view of the NoS and the relationship that existed between science and technology.

#### **6.4 The national curriculum view of the nature of science**

From a review of the literature surrounding views of the NoS (see Chapter 3) it is clear that there is no simple definition that adequately sets out a universal, uncontested definition of the NoS. The NoS is the first view set out in the proposed SNC. It states that:

Science is a human endeavour and in its current study we need to acknowledge its history and future. It is a continuous process by which individuals and groups develop an understanding of the physical and biological aspects of the world. It is a way in which reliable knowledge about the world is progressively established through the generation and testing of ideas and theories. Faced with a new phenomenon, the scientist uses existing ideas which may then be modified or rejected if they do not help to explain it. The results of this scientific endeavour are progressively more powerful ways of understanding the physical and biological world. (DES, 1988b, p.6)

The fact it is the first stated view means that from an educational perspective it was recognised by the SWG as an important foundation for teaching and understanding science. Analysing the statement above, NoS themes are discernible that characterize the SNC:

- 1) Science is a human endeavour
- 2) Science is a continuous process (from past to present leading to the future)
- 3) Science is about the understanding of natural phenomena (physical and biological)
- 4) Science requires reliability
- 5) Science is the testing of ideas and theories
- 6) Scientific knowledge is affected by social and cultural contexts

If we compare these 'themes' with the characteristics of the NoS that underpin this thesis and is my view of the NoS (Lederman and Abell, 2007) we can see a clear synergy between the statements, but also some differences.

Table 6.1 sets out both sets of characteristics/themes. The centre column provides a 'theme identifier' that will be used in the analyses of the curriculum documents as well as the interviews conducted with the interviewees with a view to identifying evidence to support the conclusions from the case study.

#### **6.5 Proposed programme of study: ages 11 – 14 & 14 – 16**

The proposed PoS for 11-14-year-olds is the first place where the NoS appears as a specific learning goal. It is contained within a section called '*Science in Action*' (DES,

1988b, pp.132-133). The NoS is introduced to children through key ideas. Table 6.2 lists the key Ideas and relates them to the NC NoS themes listed in table 6.1.

Table 6.1 Emergent themes from an analysis of the NoS curriculum statement compared to Lederman's (2007) views.

Nature of Science theme description derived from the National Curriculum statement	National Curriculum Nature of Science Theme Identifier	Characteristics of the NoS Lederman (2007)
Science is a human endeavour	<b>A Human Endeavour</b>	That science involves creativity and imagination.  That science as a human enterprise is practised in the context of a larger culture.
Science is a continuous process (from past to present leading to the future)	<b>B Continuous Process</b>	That scientific knowledge is never absolute or certain.
Science is about the understanding of natural phenomena (physical and biological)	<b>C Understanding Nature</b>	There is a distinction between observation and inference.
Science requires reliability	<b>D Reliability</b>	That there is a distinction between laws and theories.
Science is the testing of ideas and theories	<b>E Testing theories</b>	
Scientific knowledge use is affected by social and cultural contexts	<b>F Social Contexts</b>	That scientific knowledge is subjective and/or theory laden.  That science as a human enterprise is practised in the context of a larger culture.

Within the consultation document (DES, 1988b) the NoS was a full Attainment Target (AT22). The PoS, as well as being the statutory part of the curriculum, had the function of pulling the ATs together. This was the case with the '*Science in Action*' section of the curriculum, where AT21 also featured as the 'technological and social aspects of science' (DES, 1988b). There was a potential issue in linking these two attainment targets. The NoS has a social aspect (F) so the development of a separate AT for the technological and social aspects is potentially confusing or could undermine the NoS AT by implying that the social aspects of the NoS are only linked to the appliance of science as in technology. This would fit with Wolpert's (2004) view that science should be free from moral and ethical constraints. It also illustrates another problem when considering the NoS as an integrated entity within a curriculum: boundaries may be blurred. This can lead to a lack of coherence within the curriculum, one of the problems emerging from this case study.

Table 6.2. Key ideas on the nature of science derived from an analysis of the 1988 programme of study

Programme of Study 11-14	NC NoS theme	Programme of Study 14 – 16
i. The role and importance of science in everyday life	<b>A</b> <b>Human Endeavour</b>	N/A
ii. How science is applied and used in domestic, industrial and environmental contexts	<b>A</b> <b>Human Endeavour</b>	N/A
iii. The benefits and drawbacks of applying scientific concepts to themselves, the environment and the community	<b>A</b> <b>Human Endeavour</b>	N/A
iv. Make personal decisions and judgements based on scientific knowledge on matters of health, well-being, safety and care for the environment	<b>A</b> <b>Human Endeavour</b> <b>C</b> <b>Understanding Nature</b>	N/A
v. The study of ideas and theories (in history) to explain natural phenomena	<b>B</b> <b>Continuous Process</b> <b>C</b> <b>Understanding Nature</b>	VIII. Study the ideas and theories used in other times to explain natural phenomena
vi. Relate ideas and theories to present day scientific and technological understanding and knowledge	<b>C</b> <b>Understanding Nature</b> <b>D</b> <b>Reliability</b>	IX. Relate such ideas and theories to present scientific and technological understanding and knowledge
vii. Compare ideas and theories with their own emerging understandings and relate them to available evidence	<b>C</b> <b>Understanding Nature</b> <b>D</b> <b>Reliability</b> <b>E</b> <b>Testing Theories</b>	X. Compare such ideas and theories with their own emerging understanding and relate them to available evidence
N/A	<b>D</b> <b>Reliability</b>	XI. Distinguish between claims and arguments based on scientific considerations and those which are not
N/A	<b>B</b> <b>Continuous Process</b> <b>F</b> <b>Social Contexts</b>	XII. Consider how the development of a particular scientific idea or theory relates to its historical and cultural context
N/A	<b>B</b> <b>Continuous Process</b> <b>D</b> <b>Reliability</b> <b>E</b> <b>Testing Theories</b>	XIII. Study examples of scientific controversies and the ways in which scientific ideas have changed

A footnote in the proposal document states that the NoS should be delivered as a part of '*normal science studies*' (DES, 1988b, p.133). This implies that the concept of the NoS should not be taught explicitly but woven into everyday teaching.

In common with the PoS for 11-14, the NoS is incorporated into the PoS for 14-16 (table 6.2) within the curriculum section '*Science in Action*' which, as noted earlier, includes AT21 and 22. The key ideas are similar to those found for ages 11-14, and include some overlapping statements, but as would be expected they are developed further with new statements that are conceptually more difficult.

There is a crossover with the key ideas in the PoS for 11-14 and a rewording of one statement. Instead of the study of ideas and theories 'in history' (PoS 11-14) the phrase 'in other times' is used (PoS for 14-16) – (see table 6.2 row 4). These may be considered as synonymous.

The SWG is looking for a progression in knowledge and understanding of the NoS at the ages of 14-16, with statements which contain words such as 'distinguish' and 'compare', asking children to relate scientific ideas/theories to historical and cultural contexts. What is less clear is how the attainment target statements directly relate to the concepts outlined in the narrative of the PoS. While statements can be allocated to cover the various concepts (as has been illustrated in table 6.2), a natural and direct fit is not evident. For example, while the testing of ideas and theories is an explicit part of the PoS statement (E), the attainment target statements do not consider this aspect of the NoS explicitly, though it could be inferred from the statement '*Compare such ideas and theories with their own emerging understanding and relate them to available evidence*' (DES, 1988b, p.70).

The issue here is how the NoS has been separated and listed as a component part of the attainment targets, while some aspects of the NoS, e.g. the testing of ideas/theories are contained in other 'experimental' attainment targets. It is worth comparing and exploring what the key themes in the SNC are with respect to the proposed Programme of Study for Key stages 3 and 4.

#### **6.6 Attainment target 22 science in action: the nature of science**

In the consultation document (DES, 1988b), the NoS was given its own attainment target. Statements of attainment for ages 11-14 and 14–16 were also provided. These complemented the PoS and made explicit the learning for children. The clear intention of the proposals was that the NoS should not be taught as a separate entity. Its concepts were supposed to be spread across different attainment targets, especially those

targeting skills rather than knowledge. This had potential for the NoS to be ignored or not fully explained and explored by teachers. As Donnelly (2001, p.184) reports from an interview with one of the SWG, '*...it's just human nature that if you have to assess certain things, those will be what they (i.e. teachers) will teach*'. 'Teaching to the test' is not a new phenomenon and any lack of attention to the NoS could, in part, be explained by this approach. There is another issue that Donnelly does not examine in detail. In the consultation, the separate attainment target with 'expected levels of attainment' indicates that the SWG intended the NoS to be assessed and therefore taught. A problem would occur if science teachers did not appreciate the place of the NoS in the science curriculum. If teachers do not understand, or place value on the NoS, it would be unlikely that a good or sophisticated and thorough interweaving of the NoS within the teaching of knowledge and/or skills would be achieved. The teachers' Pedagogical Content Knowledge (PCK) (Shulman, 1986) would be deficient in this area.

Another issue is that these were just proposals sent out for consultation and, as such, were subject to change before any statutory regulations were made and the actual curriculum implemented. If teachers did not have a clear and good understanding of the NoS then it is likely that a complete AT on this may not be universally welcomed and could be negatively commented on in any consultation response.

In total there were six statements of attainment in AT22–The Nature of Science. Three were to be assessed at KS3 and three at KS4 (table 6.3). These statements were intended to exemplify the PoS. At KS3 they were exclusively framed within a historical or cultural approach. The children were asked to either give accounts of or compare explanations of natural phenomena from the past to the present day. To increase the challenge, children could also provide an evaluation of other people's explanations in the past or present.

At KS4 the level of difficulty in the statements increases significantly (although the expected range of levels runs from 4 to 10). The first statement, distinguishing claims and arguments requires children to have ideas about what constitutes a scientific question and the notion of falsifiability. The second statement requires a knowledge and understanding of the history of science. This is necessary not just for Western nations but is related to other cultures, e.g. Islamic science or Chinese scientific discoveries.

The final statement also requires knowledge and understanding of the history of science, but this also includes aspects of the philosophy of science and the idea of science not being about 'truth' but explanations of natural phenomena that may be revised in the light of new evidence.

Table 6.3 gives the statements of attainment for AT22. The first column indicates the age at which they are expected to be taught, the second has the statement from the curriculum and the third column the assessment level the statement relates to. The final column maps the National Curriculum NoS theme identifier.

Table 6.3 Statements of attainment for AT 22 (The Nature of Science) analyzed with respect to the derived themes (table 6.1)

Age	Statements of Attainment	Expected Range of Levels of Attainment	NC NoS Theme
11-14	Identify and give an account of the explanations for some natural phenomena that have been given by people living in other times or places in the World.	4 to 7	A: Human Endeavour
	Identify situations where people in other times, places and cultures have contributed to our present scientific understanding and technological development.		A: Human Endeavour F: Social Context
	Compare the scientific ideas or theories of other people or times with their own and evaluate these ideas in the light of evidence.		B: Continuous Process E: Testing Theories
14 -16	Distinguish between arguments and claims which are based on scientific considerations and those which are not.	4 to 10	C: Understanding Nature
	Relate a particular theory to its historical and cultural context.		A: Human Endeavour F: Social Context
	Identify areas of controversy in Science and recognize that scientific theories are provisional; that they have changed in the past and may change in the future.		B: Continuous Process D: Reliability

### 6.7 Proposed programme of study: ages 5 - 11

As noted earlier, this analysis concentrates on KS3 and 4, but it is helpful to provide a brief review and short analysis of why the NoS is not included in KS1 and 2.

Within an enacted NC, the PoS is the legally enforceable aspect of the curriculum (DES, 1989). This specifies the essential broad coverage for each subject curriculum.

The level of difficulty for the investigation ATs is, as would be expected, higher. Children were expected to explore phenomena and undertake surveys, test ideas, models and predictions, make comparisons and evaluate materials, structures and devices (DES, 1988, p.128). These are nominally linked to AT17 and AT18. The testing of ideas is part of the NoS – Theme E.

Across the primary curriculum, there was an intention to focus on investigation and practical skills. The idea of the NoS as a core and intrinsic element of teaching and learning was left to later in the curriculum. It was, perhaps, the view of the SWG that trying to deliver aspects of the NoS at such a young age would be problematic. Elsewhere in the consultation proposal (DES, 1988b, p.121) the SWG noted that research conducted by the Assessment of Performance Unit (APU) showed young children's conceptual understanding of scientific ideas was not good. It would have been reasonable to extend this, therefore, to an understanding of the NoS. The ability of non-specialist primary teachers, with few, if any, science qualifications beyond O level, also adds weight to the exclusion of the NoS from KS1 and 2.

## **6.8 Summary**

The first proposal for consultation was a departure from the concept of science as the three separate sciences of biology, chemistry and physics. Given that the 1960s, 70s and 80s had been characterised by major science curriculum initiatives such as Nuffield Sciences and the work for the Secondary Science Curriculum Review (SSCR), which produced several integrated or combined science courses, often on a topic or modular basis, this is no surprise.

The idea of taking the three separate sciences was still a dominant force at O level and the idea of a 'double science' award for the forthcoming new GCSE examinations at age 16 concerned teachers who were worried about progression to A level, which had remained almost unchanged and unaffected by curriculum developments lower down (Jenkins, 2000).

The other key reform that came with the first proposed SNC was the importance of the NoS. This was not a feature of previous public examination syllabuses and, as shown in Chapter 2, was not really a feature of the development of science as a subject to be studied in schools. The NoS, with its references to the history of science and the philosophy of science was not seen as an important aim for teaching and learning in science up to this point. The fact that it was to be taught as part of the 'normal science' content meant teachers were more likely to concentrate their efforts on teaching what was to be assessed – the scientific content – rather than the NoS. How teachers, who



were unused to teaching the NoS would integrate this into 'normal science' was also an issue.

The first consultation curriculum provided a good view of the NoS, given that there is no universally common or agreed definition that satisfies all those involved in this area of research and study.

If we consider Posner's (2004) questions in the analysis of this consultation we can draw some conclusions about the purpose, content and organisation of the curriculum.

### **6.8.1 The purpose and content of the curriculum**

The nature of science was important as it was established and defined quite early into the consultation document. The content was extensive and covered all the three main science disciplines as well as Earth science, astronomy and environmental science. This was problematic organisationally. The sheer volume of content required was too much for the space available within the school timetable, something that was part of the Dearing Review (see section 5.4.5). Too much content was bound to cause issues. As Huxley observed, *'I do not mean that every schoolboy should be taught everything in science. That would be a very absurd thing to conceive, and a very mischievous thing to attempt.'* (Huxley, 1899, p.71). Although the curriculum did not deliver all the scientific knowledge of the day, what was included was too much. There was within the curriculum a strong element of a training in science (practical skills and experimentation), with a view to increasing the uptake of science beyond age 16.

### **6.8.2 Curriculum organization**

The structure and organisation of the curriculum was fixed. It followed a pattern repeated across all subjects, with a programme of study, attainment targets and statements of attainment that were, in effect, the teaching objectives. The statements of attainment were seen as the most important aspect of the curriculum by the teachers as any assessment would be based on these content statements. In Posner's (2004) terms this was an 'ends' curriculum (see Chapter 1). There were some underlying assumptions to the curriculum and its organisation.

### **6.8.3 Curriculum assumptions**

Firstly, the content was not arranged by discipline (biology, chemistry, physics) but in the form of broad topics, e.g. human influences on the earth, forces, making new materials. There was an attempt to develop a coherent and integrated curriculum that delivered a holistic understanding of science, albeit through atomistic statements of content or knowledge.

A second assumption was that the NoS that should bind the different disciplines could be delivered through the subject content. It may seem axiomatic that if you study a subject you should gain an understanding of the ontology and epistemology of that subject. This could be delivered explicitly through direct teaching about the NoS or through integration within the teaching of other topics (what was intended). There is evidence, however, that even after the curriculum came into effect, the NoS was not planned for in teaching by science teachers either explicitly or in an integrated way (Nott and Wellington, 1996; 1998; 1999).

A third assumption was that children's progress in scientific understanding would be linear and common across the disciplines as the levels of attainment (initially 10 levels, with 1 being the lowest and 10 the highest level of achievement) were linked to the content.

A fourth assumption was that it would be possible to track children and their progress via the levels. Politically this was important as it made the schools and teachers more accountable as their efforts and effect on children could be systematically measured and comparisons made between schools or even between teachers of the same subject within schools.

Chapter 7 details how, after the consultation on this proposal had concluded, the new curriculum was developed, slimmed down and continued to evolve over the next ten years.

## **Chapter 7**

### **Curriculum Reform 1989 – 1999**

Having traced how the first curriculum proposal was constructed, utilising a wide range of expertise and viewpoints, this chapter analyses the content, with respect to the NoS, of the various versions of the SNC over the next ten years. The initial published and implemented curriculum (DES, 1989) contained a number of major revisions of the consultation document, including a reduction in content and the slimming down of attainment targets from 22 to 17. Once more, Posner's (2004) framework (see Chapter 4) will drive the analysis of the various curriculum documents and the key themes of political, educational and organisations influences will be considered (see Chapter 1).

The ten-year period covered in this chapter represented a time of intense change across the education sector with a constant writing and rewriting of schemes of work for the sciences (and other subjects) in schools by teachers and the introduction of new Government initiatives and accountability measures.

This period saw the introduction of a new GCSE grade, the A\*, in 1994. This was introduced to help employers and others distinguish between the highest attaining candidates. The pass rate, and the numbers gaining top grades, at GCSE had been increasing year on year, as had the percentage gaining an A grade. In line with Government plans, SAT tests were introduced for year six children in 1994, prior to children moving to secondary education.

After the initial proposed curriculum for science, there followed, in quick succession, five more draft and implemented versions. This led to a call for a period of stability. Widespread discontent over the curriculum triggered a review, led by Ron Dearing, which led to further reform and a promise of stability (see Chapter 5). A five-year moratorium on curriculum change was instigated in 1995 after the publication of the fifth version of the science curriculum and no more change was planned until 2000.

#### **7.1 Versions of the science national curriculum**

Following the first consultation, several versions of the SNC were produced, some in draft form, others implemented which had to be taught. Table 7.1 provides a summary of various versions analysed for this thesis.

Table 7.1 Notes on the various versions of the science National Curriculum 1988-2007

Date	Status	AT (No.)	Levels	Notes
1988	Draft	22	10	<ul style="list-style-type: none"> <li>The initial 22 AT curriculum was quickly revised though the consultation period was short.</li> </ul>
1989	Statutory	17	10	<ul style="list-style-type: none"> <li>The curriculum was introduced for KS 3 and KS1 in 1989</li> </ul>
1991	Statutory	4	10	<ul style="list-style-type: none"> <li>This was the first major review that took the topic-based attainment targets and grouped them into mostly biology, mostly chemistry and mostly physics. Some elements e.g. the Earth science was split between biology (fossils) and Chemistry (rocks and the rock cycle)</li> <li>Post Dearing consultation proposals – with a reduction in content and duplication</li> </ul>
1994	Draft	4	10	<ul style="list-style-type: none"> <li>AT 1 is called experimental and investigative science</li> <li>PoS includes the nature of scientific ideas</li> <li>Levels are reduced to 8 plus ‘exceptional performance’ (EP)</li> </ul>
1995	Statutory	4	8	<ul style="list-style-type: none"> <li>Attainment Target 1 (Scientific Enquiry) has a section ‘ideas and evidence in science’</li> </ul>
1999	Statutory	4	8 + EP	<ul style="list-style-type: none"> <li>A statement on the ‘Importance of Science’ is included.</li> </ul>
2004	Statutory	4		<ul style="list-style-type: none"> <li>Main changes are applied to KS4 only with a greater emphasis on ‘How Science Works’</li> <li>‘Key Concepts’ are introduced for HSW and content</li> <li>Scientific thinking</li> <li>Applications and implications of science</li> <li>Cultural understanding</li> <li>collaboration</li> </ul>
2007	Statutory	4	8+EP	<ul style="list-style-type: none"> <li>‘Key processes’ are introduced for practical skills, critical understanding of evidence and communication</li> <li>Range and content is again reduced and reorganized</li> <li>‘Curriculum opportunities’ are introduced</li> <li>Level descriptors for Sc3,3 &amp; 4 are provided</li> </ul>

## 7.2 Science national curriculum 1989

The draft proposals (DES, 1988b) were amended and changed following consideration of the responses to the consultation set out by the then newly formed NC Council (NCC). The final document, sent to all state-maintained schools, set out what was to be taught (DES, 1989). The folder was arranged as follows:

1. A facsimile of the 1989 Statutory Orders which required the National Curriculum to be taught.
2. The attainment targets and associated statements of attainment for Key Stages 1-3, and Model A (the full double science curriculum) for Key Stage 4.

3. The reduced attainment targets and associated statements of attainment for Model B (single science).
4. The PoS for Key Stages 1-3 and models A and B of Key Stage 4.
5. A copy of Circular 6/89 setting out the timetable for implementation, review and assessment arrangements.

In addition to the complete orders and curriculum, there was non-statutory guidance, issued by the NCC, that informed teachers how they could assess the development of knowledge and understanding within the Nature of Science AT17, but it did not state how the NoS fits in with the curriculum in any meaningful, holistic way. The non-statutory guidance indicates that the group producing the curriculum document did not feel that the NoS was well understood by teachers, otherwise specific guidance would not have been needed.

The Non-statutory guidance sought to show progression in knowledge and understanding of the NoS. It begins at level 4 because assessment of an understanding of the NoS presumed that for the primary years the concept was too difficult. There are no levels 1, 2 or 3. Progression is linear and selects what the writers of the curriculum most likely see as the most important aspects of the NoS. Progression was split into two: reflections on first-hand experience and reflections on second-hand experience. First-hand experience is very limited in this exemplification. It involves only two things: discussion and prediction, though both are also linked to second-hand experiences. Discussion is placed within level 5 and prediction, level 9. The second-hand experience is much more detailed and includes a greater number of levels:

Level 4: an account of a scientific advance

Level 7: an account of change in theory; evidence and imaginative thought

Level 8: cultural and historical

Level 10: alternative theories past or present

Level 10: uncertainty of evidence.

The 'first-hand' reflected what the children were reasonably expected to gather in a laboratory situation. The second-hand evidence reflected the use of second-hand source materials used in class. There was no exemplification for what a teacher may see at levels 5 and 6 or 9.

Anecdotally, at the time, teachers viewed such guidance as 'unhelpful'. It did not provide useful descriptors of what the levels would 'look like' in classrooms with teachers trying to assess a child's understanding of an aspect of science. Much of what teachers did

was often guesswork confirmed and moderated by other teachers in the department. In my own school, this attainment target was not seen as particularly important, so little time was devoted to working out how children could be assessed against the levels.

### 7.3 Two versions of the nature of science or one?

Donnelly (2001, p.184, Donnelly's own emphasis) claims that the first enacted curriculum for science (DES, 1989) contained '*two accounts of 'the nature of science', placed like book-ends, at the beginning and end of the statutory document*'. He was referring to AT1 and AT17 as the 'two accounts'. There are several grounds on which this characterisation can be challenged. It can be argued that the skills and processes (that is, the practical skills of science or how scientists work) does not define the NoS, it is not therefore 'an' account of the NoS. Following a method of investigation or using a scientific method does not mean that what is being investigated is scientific. If using a method of investigation was all that is necessary to define what is and what is not 'science' or 'scientific' then, as Bauer (1994, p.58) observes:

the scientific method, as classically formulated could obviously be applied by anyone to any investigation, and if it were application of the method that makes something scientific, then one could not label the study of anything "pseudoscientific" so long as the scientific method had been followed.

In this respect Donnelly (2001) is conflating the methods of science with the NoS or using TSM as a proxy for the NoS. As shown in the review of literature (Chapter 3) TSM is a discrete, though not detached, facet of the NoS. The skills and processes are part of the NoS but to state that they are 'an account' of the nature of science would, in my view, be misleading. Simply thinking of the skills and processes of science as a proxy for the NoS misses aspects of the nature of science such as creativity and imagination, or the cultural aspects of the NoS. It may be argued that skills and creativity could be utilised in developing new and perhaps novel experiments, but within the school science curriculum, the following of set procedures and experimental methods leaves little room for such creativity and imagination. Hodson (2014) details and supports the view that a single, uncontentious definition of the NoS still does not exist and he puts forward a view that school science education would benefit from a view of the NoS, '*based on scientific argumentation, modelling and consideration of socioscientific issues (SSI)*' (Hodson, 2014, p.911).

What was unclear and missing from this first taught SNC was an articulation of how the NoS forms part of the science curriculum content and how the NoS fits into conceptions of science generally. This is a major omission and limitation within the SNC. There was

a description of what the writers thought the NoS was (as shown in Chapter 6) and the idea was that the NoS should have been brought into different attainment targets rather than being taught as a discrete attainment target.

#### **7.4 How does the nature of science ‘fit’ within the science curriculum?**

For the incorporation of the NoS into ‘normal science teaching’, it would seem to be a vital step to show first how the NoS fitted into a knowledge-based curriculum. Trying to work out which aspects of science form the NoS, which are simply scientific facts or knowledge, which are skills and processes is not necessarily straightforward. Figure 7.1 sets out one conception, developed from the analyses of the curriculum of how the NoS could be informed by and subsequently inform the science curriculum.

#### **7.5 How NoS informs the science curriculum: figure 7.1 explained**

The science curriculum sets out the main scientific facts, concepts and processes that we want children to know, understand and be able to do across the science disciplines. Teachers, therefore, will have through study and experience, this tacit knowledge of science, emanating from their degree studies or their own subject knowledge acquisition. To teach the curriculum this tacit knowledge must be passed to pupils, it is knowledge that must become explicit for the teacher and this needs to be combined with their pedagogical knowledge to form PCK. The teachers’ tacit knowledge becomes explicit through the teachers’ normal work creating lessons, worksheets, reviewing textbooks etc. This ‘knowledge’ is passed to the children in several ways, e.g. through direct instruction, problem solving approaches, through practical lessons and investigations (scientific inquiry) and with secondary materials such as textbooks, videos etc. This then contributes to an explicit knowledge of science, which is most often tested through examination of content and production of laboratory based practical work (coursework).

Aspects of the history of science, philosophy of science and scientific inquiry inform the NoS which can lead to an explicit NoS component. Ideally, this should also add to the explicit knowledge of science and provide more dimensions into how science is conducted by making explicit the deductive, inductive and abductive logic/thinking required in different science disciplines. If all aspects of science, from knowledge to inquiry and understanding of the NoS are well integrated it should make for a more rounded and better science education with children being able to understand scientific processes and procedures and be able to evaluate knowledge (established and new). It does, in effect, lead to good scientific literacy.

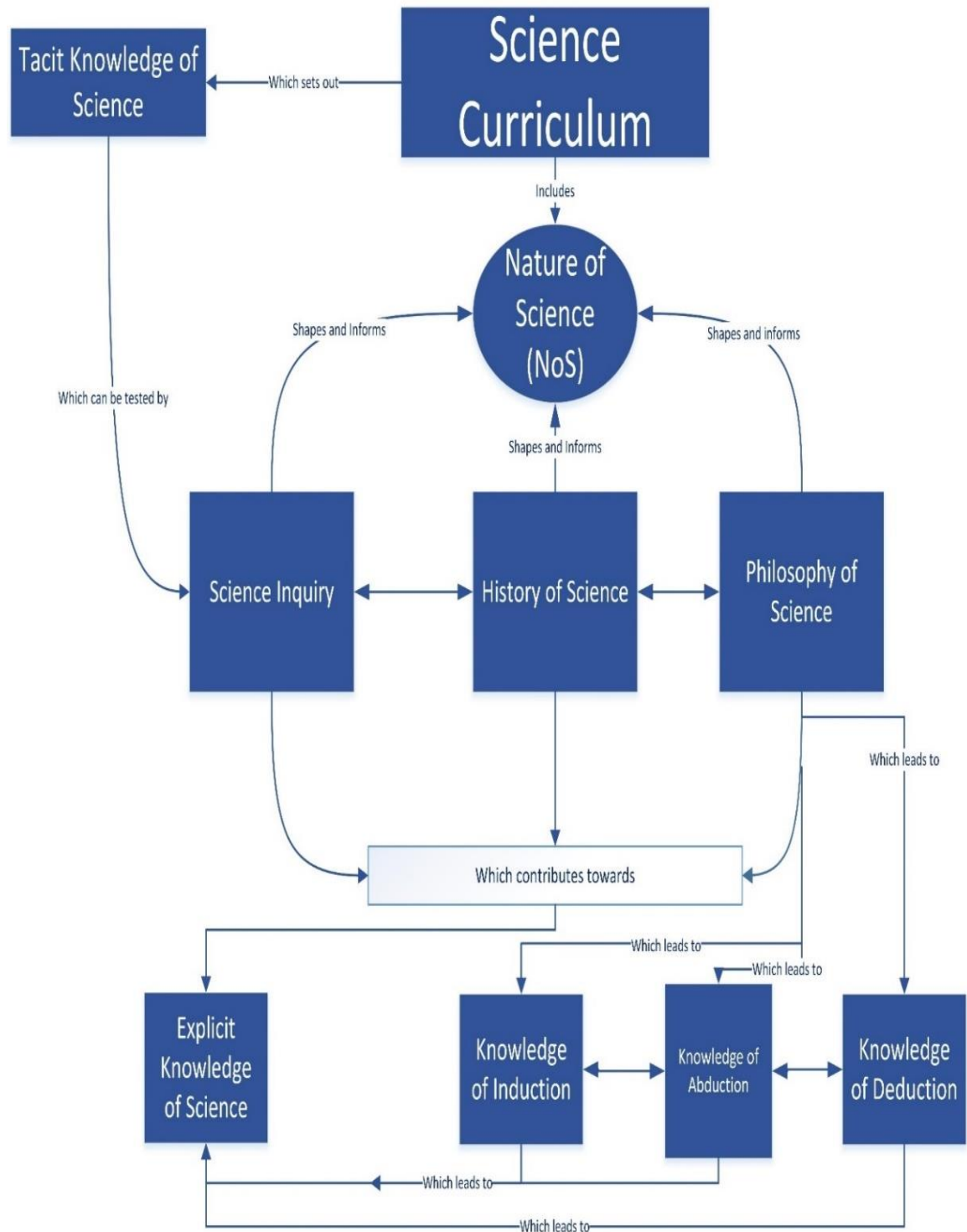


Figure 7.1 How the NoS could inform the science curriculum

### 7.6 A science curriculum without an integrated NoS

What the SNC put into operation in 1989 did not do is make clear how the NoS fitted into this broader picture of science. It gave no indication of any philosophical underpinning.



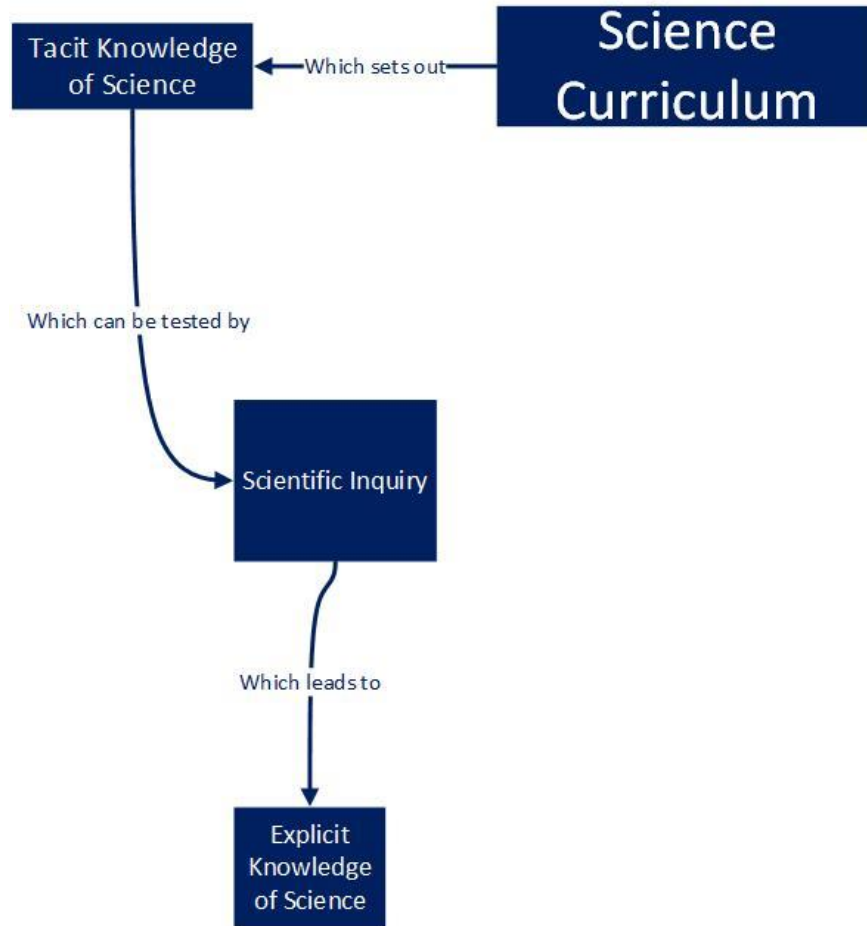


Figure 7.2 A science curriculum without an integrated NoS element

This meant that the NoS was neither appreciated by teachers nor seen as a vital component. It was ostensibly a utilitarian curriculum, which delivered factual knowledge and skills. It led to teachers delivering a curriculum that transmitted a knowledge of scientific concepts and the ‘facts’ of science. Alongside this they delivered a skills agenda in some of the methods of science, but without any real articulation of the inductive, deductive or abductive nature of scientific inquiry with elements of the ‘history of science’ viewed simply as add on contextual information about the origin of some scientific ideas and how they change over time.

The 1989 SNC was still viewed by teachers as too complex, content laden and difficult to deliver in the limited time allowed by schools for the teaching of science. Almost immediately, another revision of the curriculum was ordered.

### **7.7 The post 1989 draft science National Curriculum for science**

The post-1989 draft proposals (DES, 1991a) were never implemented and were amended considerably after an initial consultation. This draft version of the NC had five ATs formulated as New Attainment Targets (NATs). Table 7.2 shows the configuration of the NATs and their relationship to the first (1989) NC document. This consultation version took a pragmatic approach to grouping together the 22 original attainment targets into the broader disciplines of biology, chemistry and physics with an added discipline of Earth and the environment.

A report on the consultation (Pascall, 1991) noted that there were concerns about overlap between the geography and science curriculum. In particular, NAT3 on the Earth and environment contained overlapping material with the geography NC. As a result, the NCC removed the geographical elements from the science draft which left this new attainment target with fewer statements of attainment than the others. This had implications with respect to the weighting of the target for assessment meaning that this new attainment target could *'assume an inappropriate significance in the context of reporting to parents'*. (Pascall, 1991, p.10) As a result, the NCC suggested a four-attainment target curriculum. The NoS was much reduced but was still thought to be important enough to be included. That said, Model B of this curriculum (single science) had no statements of attainment relating to the NoS, thereby indicating that it was viewed as expendable content that had a less important role in teaching science than the facts of science. The NCC recommended reintroducing statements on the NoS within the new AT1.

### **7.8 The 1991 enacted science national curriculum**

The revised and enacted 1991 SNC (DES, 1991b) was significantly different from the first curriculum. The changes came because of legal difficulties and feedback from teachers (and others) which considered the curriculum as too detailed and, therefore, difficult to teach and assess. The legal issue was that each AT needed to be assessed separately. With seventeen ATs this would be administratively complex and difficult to implement educationally and organisationally.

The revision was carried out by a team of six HMI science inspectors (Black, 1995a). This marks a major change from the construction of the first curriculum where science educators and a broad range of people working in science education constructed the curriculum. The restriction of this revision to a small, more easily controlled group of inspectors represented a move to a more centralised, politically controlled curriculum (Black, 1995a; 1995; Donnelly, 2001).

Table 7.2 Comparison of the new attainment targets in the 1991 NCC Consultation with 1989 SNC

New Attainment Target (NAT)	Content	Relationship to old ATs
Scientific Investigation	Hypothesizing and predicting	1: Exploration of science
	Observation and Measurement	
	Interpreting results and drawing inferences	Part of 12: The scientific aspects of information technology including microelectronics
	Scientific Evidence and theory	Part of 17: The nature of science
Life and Living Processes	Processes of life	3: The processes of life
	Variation and heredity	2: The variety of life
	Factors affecting population	4: Genetics and evolution
	Cycles of energy and nutrients	5: Human influences on the Earth
Earth and environment	Weather and atmosphere	9: Earth and Atmosphere
	Rocks and soil	
	Exploitation of energy resources	most of 13: Energy
	The Earth in space	16: The Earth in space
Materials and their behaviour	Types and uses of materials	6: Types and uses of materials
	Making new materials	7: Making new materials
	Explaining how materials behave	8: Explaining how materials behave
Energy and its effects	Energy and forces	Part of 13: Energy 10: Forces
	Electricity and magnetism	11: Electricity and magnetism
	Light and sound	14: Sound and music 15: Using light and electromagnetic radiation
		Part of 12: The scientific aspects of information technology including microelectronics

The seventeen original attainment targets (ATs) were reduced to just 4. These were AT1: Scientific investigation; AT2: Life and living processes; AT3: Materials and their properties and AT4: Physical processes. The final three attainment targets were known colloquially as 'mostly biology, mostly chemistry and mostly physics'. Within biology resided some aspects of earth sciences in the form of fossils and evolution over geological time. Within chemistry resided rock types, aspects of meteorology and, at Key Stage 4, plate tectonics. Within physics there was reference to astronomy and the motions of planets in the solar system.

The NoS as a distinct and separate attainment target had been abandoned. Importantly, the PoS still maintained the concept of the nature of scientific ideas and this was summed up in one short paragraph at the start of each Key Stage. This move from the status of a full attainment target to a mention in the programme of study effectively killed off the notion of the NoS being delivered coherently across the curriculum by teachers. The teachers knew that what would be assessed was contained in the statements of attainment and they would concentrate their efforts on teaching those. While AT1 was about scientific investigation, this was a skills-based component and the idea of critical thinking skills or forms of logic, which are essential to the NoS were not apparent.

At Key Stages 1 and 2, the NoS is not mentioned explicitly, but is captured in statements under the heading 'Science in everyday life'.

At KS3 the following statement is found:

**The nature of scientific ideas:** pupils should be given opportunities to develop their knowledge and understanding of how scientific ideas change through time. They should study the development of some important ideas in science. (DES, 1991b, p.13)

Comparing this statement to the original NoS view in the original 1989 science curriculum and the themes derived from this (see Chapter 6), it only covers theme B (Continuous Process). Themes A (Human Endeavour), C (Understanding Nature), D (Reliability), E (Testing Theories) and F (Social Contexts) are absent.

At KS4 (double science and single science versions) the PoS includes the following statement for the NoS:

**The Nature of Scientific Ideas:** pupils should be given opportunities to develop their knowledge and understanding of how scientific ideas change through time and how the nature and the use to which they are put are affected by the social, moral, spiritual and cultural contexts in which they are developed. In doing so they should begin to recognize that, while science is an important

way of thinking about experience it is not the only way (DES, 1991b, pp. 22 & 32)

Comparing this statement (as above) we can see that theme B (Continuous Process) remains and theme F (Social Contexts), is present, but themes A (Human Endeavour), C (Understanding Nature), D (Reliability) and E (Testing Theories) are absent. These themes are seen in part (at Key Stage 3 and 4) in other aspects of the curriculum. The result of splitting the key components of the NoS and placing them in different parts of the curriculum results in a less coherent curriculum. What should bind together and underpin science as a subject is now no longer apparent or accessible to teachers.

It is difficult therefore to make a case here that the statements represent a coherent articulation of the NoS. It is evident that this aspect of the science curriculum was deemed far less important than a simple accruing of science knowledge and skills.

### **7.9 Scientific investigation and the NoS: the 1991 science curriculum**

In the 1991 SNC (DES, 1991b), in KS3, AT1: scientific investigation, it is evident that the processes of science, the methods employed, are paramount. The whole target consists of statements of attainment geared towards measuring, quantifying, testing and looking for patterns. There was a focus on things such as variables, predictions from prior knowledge and the validity of conclusions.

At KS4, in the same AT, a similar pattern of statements of attainment is found, concentrating on measurements, fair tests, variables etc. At KS4, however, terms such as hypothesis and theory are used for the first time, as is the concept of causal links. Theory is also used with respect to the prediction of relationships between continuous variables. At the highest level (10) children were required to:

use their scientific knowledge and understanding of laws, theories and models to develop hypotheses which seek to explain, the behaviour of objects and events they have studied and further to use and analyse data obtained to evaluate the law, theory or model... (DES, 1991b, p.24).

One emergent theme from this analysis is that the language of science and the use of scientific language related to the NoS (theory, hypothesis etc.) is being assumed as 'understood' and that these terms mean the same thing across all the science disciplines. There is nothing within the curriculum that specifies exactly what the terms mean so that a coherent and common understanding of scientific language was taught.

In the programme of study linked to AT1 in KS3 there is just one statement that is wholly concerned with the NoS; *'offer opportunities to understand the limitations of scientific*

*evidence and the provisional nature of proof* (DES, 1991b, p.14). This statement matches theme D, that science requires reliability, and theme B, science is a continuous process. ATs 2, 3 and 4 contained no statements that directly related to the NoS.

At KS4, in the programme of study for AT1, the statement that relates to the NoS is enlarged from KS3 and encourages children to:

explore the nature of scientific evidence and proof but in addition they should also:

- distinguish between claims and arguments based on scientific considerations and those which are not;
- distinguish between generalisations and predictive theories;
- study examples of scientific controversies and the ways in which scientific ideas change. (DES, 1991b, p.23)

While there is evidence of a progression as shown in the statements above, the shift from a full attainment target to being included as a small aspect of AT1 with more detail in the Programme of Study potentially reduced its visibility to teachers as a discrete aspect of the curriculum. A comparison of the reduced statements to the themes, only theme F, scientific knowledge use is affected by social and cultural contexts, is apparent in the final statement about scientific controversies. Key aspects of the NoS are present in all the statements, but again there is evidence here relating to the thesis themes on scientific language and scientific thinking. The ability to distinguish between claims and arguments would require a working knowledge of argumentation and logical thinking. The ability to distinguish between generalisations and predictive theories assumes that teachers and children understand what scientific theories are and how these differ from the vernacular use of the term theory to mean a hunch or a guess. The research evidence as cited earlier (Williams, 2013), shows this is not necessarily the case.

In summary, there is an obvious shift in how the NoS is viewed. No longer are the 6 elements identified and expanded upon in chapter 6 explicit. The social and cultural concepts (F) may be implied but are not explicit. The idea of reliability (D) is now wholly contained within the processes of science alongside validity. Even the idea of reliability has a subtly different meaning within the NoS as compared to the process of science. In the process of science reliability would refer to measurements, instruments etc. Within the NoS reliability is more about the reliability of the explanations provided for natural phenomena.

Science as a human endeavour (A) is also now implicit rather than explicit. What resulted was an atomistic approach to the NoS with a few elements related to testing ideas

(theories). Any underpinning epistemology had been cut loose to be replaced by a curriculum that was simply about the accumulation of scientific facts and experimental skills. In addition, a lot of the intellectual engagement through a study of the history and philosophy of the subject was lost.

Although the PoS represented the statutory part of the curriculum, teachers focused on the statements of attainment as the elements that needed to be taught (Donnelly, 2001). These were the elements that were being assessed. For the NoS to be effectively delivered there needed to be specific NoS statements of attainment. These were few and far between at KS3 and were linked to the higher levels at KS4, e.g. in AT1 at KS4 only at levels 9 and 10, the highest levels of attainment, do we find statements of attainment that link directly to the NoS:

Level 9c) analyse and interpret the data obtained, in terms of complex functions where appropriate, in a way which demonstrates and appreciation of the uncertainty of evidence and the tentative nature of conclusions (DES, 1991b, p.24).

Here we see a link to Popper's claim that science cannot produce certainty. All scientific claims are tentative. Science seeks not to confirm or provide any form of 'truth' but is a system of testing ideas, what Popper called falsifiability (Popper, 2002). At level 10, in AT1 children were required to evaluate the extent to which a law, theory or model could explain '*observed behaviour*' (DES, 1991b, p.24).

Associated with each statement of attainment are 'examples' of what could be done in teaching. For level 9, the example was that of recording the corrosion rate of aluminium cooking pots. This example would be difficult to use to show the tentative nature of conclusions given the complexity of obtaining good measurements and linking this to any accepted theory about the health hazards of using aluminium cooking utensils. ATs 2, 3 and 4 contained no statements that directly related to aspects of the NoS.

The NoS had effectively been written out of the curriculum. This was a fully utilitarian curriculum that prioritised knowledge and skills over an understanding of what science 'is' or 'is not'. It was more atomistic than holistic and created an almost false view of science as being characterised by its methodologies and a body of knowledge that is to be 'learned'. There was a loss of coherence within the curriculum due to the changes, though the argument could be made that by abandoning the topic approach and reverting to the 'three sciences' approach teachers felt more comfortable and it had the appearance of a more coherent curriculum.

### **7.10 Dearing review draft version of the science National Curriculum**

In 1994 a review of the national curriculum was conducted by Sir Ron Dearing (1994), during Gillian Shephard's time as Secretary of State for education. The purpose of the review was to slim down what was recognised as an over-burdened curriculum. The review was conducted across all national curriculum subjects. It also focussed on how the curriculum would be assessed and looked carefully at the ten levels of attainment (Daugherty, 2004).

Following the Dearing review, a new draft version of the SNC (SCAA, 1994) recommended reducing the content and complexity of the curriculum. It came close on the heels of the implemented 1991 version (DES, 1991b). All children were subject to the 1991 version from 1<sup>st</sup> August 1993, and in March/April 1994 this new draft version for consultation was sent to schools for comment. It contained revisions in line with Dearing's review (SCAA, 1994), in particular an expanded role for AT1 Scientific Investigation, to include a broader range of experimental work and a better balanced programme of study for single award science, although the absence of NoS material was not addressed for either the single or the double GCSE award.

### **7.11 The 1995 Science National Curriculum**

This 1995 version of the science curriculum (DfE, 1995) split the programme of study (PoS) into five components. These components applied across all the subsequent attainment targets.

- 1) Systematic enquiry.
- 2) Application of science.
- 3) The nature of scientific ideas.
- 4) Communication.
- 5) Health and safety.

This marked a return, in part, to the original conception of the NoS. It also introduced a new facet – creative thought. In this version of the NoS there were three core ideas in the KS3 PoS:

- a) The importance of evidence and creative thought.
- b) The use of empirical evidence.
- c) Social and historical contexts of ideas and how ideas change over time.

Despite this return to more traditional and core ideas of the NoS, the emphasis on the processes of science is clear. The first attainment target, experimental and investigative



science, concentrates on how scientific knowledge is used and how the methods of science are implemented. The attainment target requires children to use a range of apparatus with skill, to make repeated measurements, record data systematically etc. This is, once more, a utilitarian curriculum that is more a training in the methods of science than delivering an epistemological or ontological understanding of what science 'is'.

At KS4, the statement on the nature of scientific ideas does change and it does represent a progression from KS3. The curriculum required an understanding of the basis on which scientific ideas are accepted or rejected – though at no point does the curriculum require any investigation of how we would know whether an idea is scientific (a key characteristic of the NoS). What the curriculum PoS does require is that there is consideration of how the context (social and historical) may affect the acceptance or rejection of an idea (note, the term idea is used not theory) this fulfils theme F (Social Contexts) from the original view of the NoS.

### **7.12 Summary**

This ten-year period was one of major change and numerous revisions to the science curriculum. During this period, the educational concerns were considerable. The 1989 curriculum once introduced was complex and contained far too much content to be delivered in the time suggested or available in schools. It was quickly apparent that a new, revised curriculum was required.

As well as curriculum changes, teachers were also coming to terms with new assessment regimes, from the end of Key Stage tests to new GCSE examinations that 'combined' the old O level and CSE but were fundamentally different in their approach to testing. This period also saw structural changes to schools – because of the 1988 ERA – that saw LEA control over schools and budgets severely cut back. This led to the loss of many support groups (e.g., LEA advisers, Heads of Science groups) for schools.

The NoS struggled to maintain its position as a core element of the curriculum, despite its survival in the programme of study, following the demise of a full NoS attainment target. Reviews of the curriculum almost eliminated it in 1991. By 1995 it had made a return under the guise of '*The nature of scientific ideas*'. This was not an attainment target, but a 'profile component' that applied across all the content. Teachers, of course, were concerned with what was to be assessed rather than what was not. Profile components as such were not assessed, at least not in a systematic and clearly identifiable way.

The advent of league tables during this period enhanced the role of assessment in the judgement of schools by OFSTED, itself a relatively new accountability system. Teacher union action and boycotts of the end of Key Stage tests, saw an end to the test at age 7, but those at age 11 and 13 remained. Teachers were being scrutinized in a way they had never been before; accountability to central government was in force. The NoS sat quietly in the background, but it was unlikely to be prioritised by teachers as something that would be of any great importance in boosting their teaching or children's performance in examinations. In response to teachers' concerns over constant change, a period of stability was introduced in 1995. The NoS also appears to have an 'identity crisis' related to the framework within which it is viewed. At times, it is part of the processes and skills of science, at other times it is more epistemological and related to how scientists construct their knowledge and understanding of nature.

## Chapter 8

### Curriculum Reforms 1999 – 2010

The period of stability and the moratorium on change introduced in 1995 was intended to let teachers get to grips with what had been a major innovation in the state education system. Prescribing what teachers must teach over letting them decide (or, at ages 14-16, deliver a prescribed syllabus) meant a huge change in working practices.

The moratorium meant that the earliest any new curriculum could be implemented was in the year 2000. As some noted, the period of five years should have been sufficient for teachers to, *'get the curriculum and associated assessment arrangements under control'* (Russell *et al.*, 1995, p.491), provided support was in place.

This chapter looks at the period between 1999 and 2010. The period is marked by a move towards promoting knowledge, understanding and skills across subjects, linking together elements of the structure of the various subject curriculum documents.

#### 8.1 Education influences from 1999 – 2010

A major report, commissioned and published by the Nuffield Foundation during the five-year moratorium on curriculum change, looked ahead to what science education should be like 'Beyond 2000' (Millar and Osborne, 1998). This influential report sought to define what a compulsory science education should deliver for all children. From this report, a new approach to science at KS4 was developed that ultimately resulted in a specification still available as an examination today, 21<sup>st</sup> Century Science. This course had the NoS at its core and, as such, was very different from most science examination courses available to schools.

Concerns over examinations, following the introduction of GCSEs, now shifted towards the 'gold standard' A level examination system. It was being recognised that there was a lack of coherence between these two phases of education. In 2000 a major review and reform of GCE A levels resulted in a modular approach. At the same time a new examination, Advanced Supplementary (AS) was introduced to provide an early indication of student attainment.

In 2008, in a move that mirrored what had happened at GCSE, new approaches to the marking of AS and A level examinations resulted in the introduction of a new A\* grade. This was accompanied by a continuing argument over year-on-year 'grade inflation' and claims that the education system was being 'dumbed down' (Lightfoot, 2010). An

OFQUAL report from 2009 confirmed some fears over the standards of GCSE science examinations. The report revealed '*a number of concerns regarding the validity and reliability of different assessments*' and concerns over the assessment of 'how science works' (Garnham, 2009; OFQUAL, 2009, p.2).

Discontent over end of Key Stage tests (SATs) was also evident. Teachers at secondary level did not trust the SATs levels being awarded at KS2. In a move initially supported by many teachers, in 2009 the KS3 SATs were scrapped completely and the examination of science at KS2 was also stopped.

## **8.2 Science: the national curriculum for England**

The next version of the SNC (DfEE, 1999) encompassed some whole school developments that affected how the science curriculum would be taught. A new section, learning across the NC, was introduced that required teachers to integrate their teaching with the aims and content of other relevant curriculum subjects. In addition, a new overarching statement on the importance of science in the curriculum was included.

This curriculum included reference to the forthcoming compulsory and new area of citizenship in the curriculum, which was to be introduced in 2002. All curriculum subjects were required to address aspects of this new curriculum requirement. Within science, the spiritual, moral, social and cultural development was made explicit and examples of how the curriculum could address these were provided.

The introduction to this new version of the science curriculum suggested the promotion of spiritual development through questions such as '*when does life start?*' and '*where does life come from?*' (DfEE, 1999, p.8). Both questions can be the subject of scientific investigation or determination. Both may also be questions that concern those who are spiritual or religious by nature, but the methods employed to answer the questions and what constitutes 'evidence' will be very different depending on whether you approach the question from a scientific or religious/spiritual dimension. In this respect, a good understanding of the NoS would be very helpful to teachers and the children studying science under this curriculum.

## **8.3 The Importance of Science**

A new statement on the importance of science was included in the 1999 version of the science curriculum (DfEE, 1999). While this is not directly a statement on the NoS it does contain aspects of the NoS.

The statement was preceded by quotations from notable scientists, such as Professor Susan Greenfield; Colin Tudge (science writer); Brendan O'Neill (Imperial Chemicals) and Professor Malcolm Longair (Institute of Physics) on their views of the importance of science. The statement read as follows:

Science stimulates and excites pupils' curiosity about phenomena and events in the world around them. It also satisfies this curiosity with knowledge. Because science links direct practical experience with ideas, it can engage learners at many levels. Scientific method is about developing and evaluating explanations through experimental evidence and modelling. This is a spur to critical and creative thought. Through science, pupils understand how major scientific ideas contribute to technological change – impacting on industry, business and medicine and improving quality of life. Pupils recognise the cultural significance of science and trace its worldwide development. They learn to question and discuss science-based issues that may affect their own lives, the direction of society and the future of the world. (DfEE, 1999, p.15)

This statement explicitly introduces ideas to science teaching and learning which were previously either absent or implicit at best – the notions of creativity and curiosity; creativity in thinking as well as critical thought; the cultural significance of science and the worldwide development of science.

An analysis of this statement using the themes generated from the original NoS statement (see Chapter 6), clearly shows theme A, science is a human endeavour, is a prominent component. Explicit and implicit reference to science as a human endeavour exists e.g. exciting pupil curiosity, creative thinking, cultural significance. There are also strong links to theme F, how scientific knowledge use is affected by social and cultural contexts. There is also a link with theme B, science as a continuous process as the statement mentions 'the future of the world'. Theme C, understanding natural phenomena, is also apparent with reference to developing and evaluating explanations. Alongside the attainment targets that set out the content were side-notes that provided cross curricular links and more detail on how attainment targets should be delivered.

The first attainment target, titled experimental and investigative science in the 1995 version, was now renamed 'Scientific Enquiry (sic)'. This was further sub-divided into 2 sections: Section 1, Ideas and Evidence in Science and Section 2, Investigative skills.

#### **8.4 Ideas and evidence in science – 1999 statements of attainment**

The inclusion of a separate section in AT1 - Scientific Enquiry (sic), in the 1999 curriculum (DfEE, 1999) represents a step back towards considering (and assessing) aspects of the NoS within the science curriculum. Ideas and Evidence in Science, although brief, does consider a few key elements of the NoS (tables 8.1 and 8.2).

Table 8.1 Key Stage 3: Ideas and Evidence statements of attainment

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**Sc1 Scientific Enquiry****Ideas and Evidence in Science**

1 Pupils should be taught:

- a about the interplay between empirical questions, evidence and scientific explanations using historical and contemporary examples [*for example Lavoisier's work on burning, the possible causes of global warming*]
  - b that it is important to test explanations by using them to make predictions and by seeing if the evidence matches the predictions
  - c about the ways in which scientists work today and how they worked in the past, including the roles of experimentation, evidence and creative thought in the development of scientific ideas
- 

A comparison of these statements against the themes derived from the 1989 curriculum shows that all the themes A - F are present, with the addition of the idea of creativity.

Table 8.2 Key Stage 4: Ideas and Evidence statements of attainment

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**Sc1 Scientific Enquiry****Ideas and Evidence in Science**

1 Pupils should be taught:

- a how scientific ideas are presented, evaluated and disseminated [*for example, by publication, review by other scientists*]
  - b how scientific controversies can arise from different ways of interpreting empirical evidence [*for example Darwin's theory of evolution*]
  - c ways in which scientific work may be affected by the contexts in which it takes place [*for example social, historical, moral and spiritual*], and how these contexts may affect whether or not ideas are accepted
  - d to consider the power and limitations of science in addressing industrial, social and environmental questions, including the kinds of questions science can and cannot answer, uncertainties in scientific knowledge, and the ethical issues involved
-

As with Key Stage 3, when these statements are compared to the original 1989 themes, all themes A-F are present. As in previous versions of the science curriculum, this attainment target was not to be seen in isolation from the content laid out in the ‘mostly’ biology, chemistry and physics attainment targets.

The way the statements are written, their relationship to direct aspects of the NoS may not have been clear to all teachers. I suggest that it would take familiarity and secure understanding of the NoS to create the links between these statements and the NoS. For example, at KS3 (table 8.1), statement **a)** invites children to consider the interplay between empirical questions, evidence and scientific explanations. Here the teacher would have to teach about what makes a scientific question as opposed to a question that science could not answer. A question such as *‘does the shade of red of a strawberry indicate how sweet it is?’* may be an empirical question that children could investigate by measuring the sugar content against the different shades of red. Another question: *‘is it possible to prove the Loch Ness monster does not exist?’* is not a scientific question as it is impossible to prove that something does not exist (though we could provide a statement on the likelihood), but a question such as *‘is it possible to prove the Loch Ness monster does exist’* could be answered. Such questions provide us with clues to the NoS and the limitations of science.

Statement **b)** at KS3 refers to testing ideas and making predictions. This is clearly part of the NoS and related, as indicated earlier, to Popper’s ideas on the NoS. Statement **c)** on how scientists work and how ideas are disseminated is not strictly the NoS as it covers the methods of science and the dissemination of scientific knowledge.

At KS4 (table 8.2), statement **a)** carries on from KS3 looking at how science is communicated rather than the NoS. Statement **b)** does consider scientific controversies and this can be interpreted as encompassing aspects of the NoS. The interpretation of evidence – the use of deductive, inductive or abductive approaches - would be part of this aspect of ideas and evidence, though these logical processes are not explicit.

The example given in the curriculum (DfEE, 1999, p.37), *‘Darwin’s theory of evolution’*, is not helpful with respect to the NoS. The ‘controversy’ in Darwin’s ideas is not elaborated upon in the curriculum. This meant that, at the time of publication, some creationist groups, such as *Truth in Science* used this example as a means for injecting creationist ideas into mainstream teaching, a tactic they still use today (Anonymous 2006; Anonymous 2016b). The ‘controversy’, creationists decided, was the validity of evolution as a theory and its opposition to a strict biblical interpretation of the Genesis

story of creation as a 'scientific' account of how evolution is 'false' and the creation of individual 'kinds' was 'true'.

A genuine controversy in evolution could be taught e.g. the idea Eldredge and Gould (1972) presented of punctuated equilibrium (periods of rapid change and speciation, punctuated by long periods of minimal change) as an alternative to phyletic gradualism (slow, incremental changes over time) as advocated by Charles Darwin. Not specifying a context for what the nature of the controversy is in evolution assumed that science teachers fully appreciate and understand the concept of evolution and associated issues such as creationism.

Statement **c)** also covers aspects of the NoS bringing in social and moral contexts. Statement **d)** is the most NoS compliant statement as it tackles the key area of the limitations of science, discussion of the kinds of questions science can and cannot answer as well as moral and ethical issues involved in scientific matters.

### **8.5 The 2004 National Curriculum for Science**

In February 2004 a revised (rather than a 'reformed') version of the NC for Science was published (DfES, 2004). This involved a simplification of structure and reduction in content. Although heralded as a revision, the curriculum for KS3 remained the same as the previous 1999 version. KS4 however was greatly modified. Attainment target 1 was renamed 'How Science Works' and the statements of attainment completely revised. The elements colloquially known as 'mostly biology, chemistry and physics', were considerably reduced and organised under the heading 'Breadth of Study'. Breadth of study contained 4 areas:

1. Organisms and health
2. Chemical and material behaviour
3. Energy, electricity and radiations
4. Environment Earth and universe

### **8.6 How science works and the nature of science**

When the phrase 'How Science Works' (HSW) was first published there was no written underlying conception for teachers of what the phrase encompassed, or how it should be interpreted or linked to such concepts as the NoS. Table 8.3 links the statements for How Science Works to the original 1989 view of the NoS and the themes that emerged from the analysis of that statement. Comparing the emerging themes to the 2004 version, HSW shows that an explicit mention of science as a human endeavour (theme A) is missing. It could be argued that this is just a function of how the statements have been



written, paradoxically, in the way that science traditionally has tended to report the results of investigations and experiments, in an impersonal way.

Table 8.3 Analysis of the 2004 Science National Curriculum 'How Science Works' Statements

<b>How Science Works</b>		
<b>1. Data, evidence, theories and explanations</b>		
Statement		NC NoS theme
C	How explanations of many phenomena can be developed using scientific theories, models and ideas	<b>C: Understanding Nature</b> <b>E: Testing Theories</b>
D	That there are some questions that science cannot currently answer, and some that science cannot address	<b>C: Understanding Nature</b>
<b>2. Practical and Enquiry skills</b>		
Statement		NC NoS theme
A	Plan to test a scientific idea, answer a scientific question, or solve a scientific problem	<b>E: Testing Theories</b>
<b>3. Communication skills</b>		
Statement		NC NoS theme
A	recall, analyse, interpret, apply and question scientific information or ideas	<b>D: Reliability</b>
B	use both qualitative and quantitative approaches	
C	present information, develop an argument and draw a conclusion, using scientific, technical and mathematical language, conventions and symbols and ICT tools	
<b>4. applications and implications of science</b>		
Statement		NC NoS theme
A	about the use of contemporary scientific and technological developments and their benefits, drawbacks and risks	<b>F: Social Contexts</b>
B	to consider how and why decisions about science and technology are made, including those that raise ethical issues, and about the social, economic and environmental effects of such decisions	<b>F: Social Contexts</b>
C	how uncertainties in scientific knowledge and scientific ideas change over time and about the role of the scientific community in validating these changes.	<b>B: Continuous Process</b> <b>F: Social Contexts</b>

### **8.7 The 2007 Version of the Science National Curriculum**

Changes to GCSE were heralded in 2006 that allowed children to choose a variety of routes to gain qualifications in science. Five different routes were available using a mixture of GCSE single or double science, other single science disciplines as well as BTEC science or a simple entry-level certificate. A new revised curriculum was available in 2007 (DCSF, 2007). This curriculum had an entirely new structure, quite different from previous versions.

The curriculum was divided into 4 sections, plus a series of level descriptors for each of the four attainment targets.

Section 1 – Key Concepts

Section 2 – Key Processes

Section 3 – Range and Content

Section 4 – Curriculum opportunities

### **8.8 Key concepts, and the nature of science**

In this new science curriculum (DCSF, 2007, p.208), Section 1, 'Key Concepts', according to the curriculum document, '*underpin the study of science and how science works*'. This marks a return to aspects of the NoS, mostly under headings such as scientific thinking; applications and implications of science and cultural understanding. Other aspects of the NoS can be found in section 2, critical understanding of evidence and section 4, which encourages creativity and innovation as well as an exploration of contemporary and historical scientific developments. Each section also has useful explanatory notes that expand on the points listed. The explanatory notes have three paragraphs relating to the NoS. These link to the statements of attainment and will be considered together (DCSF, 2007, p.208).

### **8.9 Scientific Thinking**

Scientific thinking is characterised in this curriculum using scientific ideas and models to explain phenomena. This links to theme C (Understanding Nature) from the original NoS statement from 1989. This is expanded to include creative development '*to generate ideas and theories*'. This is an inductive approach to science. In the explanatory notes, there is reference to the limitations of science and the idea that '*science is not yet able to explain all phenomena*' and that sometimes new evidence can be '*conflicting*' (DCSF, 2007, p.208). The second statement in scientific thinking requires children to analyse

and evaluate evidence from observations and experiments. This links to themes C (Understanding Nature), D (Reliability) and E (Testing Theories).

For the first time in any of the science curriculum documents, theories are expanded upon in the explanatory notes. They are characterised as being '*consistent, comprehensive, coherent and extensively evidenced explanations of aspects of the natural world.*' It goes on to state that theories can '*in principle, be tested by observations and/or experiments*' (DCSF, 2007, p.208)

### **8.10 Applications and Implications of science**

Applications and implications of science deals with creativity within science and the ethical and moral implications of scientific discoveries. The explanatory notes cover a range of situations where moral and ethical considerations would apply e.g. selective breeding, genetic engineering, production of hazardous chemicals. In particular, the use of animal experimentation in the development of life prolonging drugs for humans is cited. Clearly ethical and moral behaviour within science is part of the NoS. As discussed earlier, this aspect was implicit in a consideration of the Social and Cultural concepts set out in the first proposed curriculum. In this 2007 version, it is separated from social and cultural understanding, which is dealt with in isolation.

### **8.11 Cultural Understanding**

A single statement looks at the historical roots of science as a discipline. It refers to the fact that science has developed within many societies and cultures and that there is a variety of approaches to scientific practice (a clear link to theme A: Human Endeavour and B: Continuous Process). The explanatory notes have no further detail on this aspect of the NoS. By divorcing this from the question of moral and ethical approaches to science the curriculum appears to ignore that over time our moral and ethical standards will vary. In the teaching of science, it is to be hoped that teachers would provide examples from the history of science that today would be questionable morally and ethically, e.g. the 'vaccination' of James Phipps by Edward Jenner on 14<sup>th</sup> May 1796 to show that cowpox prevents people from catching smallpox. Today, such a practice would be morally and ethically condemned.

### **8.12 Periods in the evolution of the science curriculum as revealed by curriculum analysis**

The analysis of various government policy documents, reports and other documentation, alongside versions of the SNC with reference to the NoS, tells an interesting story. Across time we have an unfolding narrative that pits educators against politicians and policy against practice. Overall, looking across all versions of the SNC analysed in

Chapter 6,7 and this Chapter, the curriculum seems to have gone through three distinct periods.

**Period One** – The decision to create a NC was essentially a political one. There are clear political influences in how the curriculum was constructed, which subjects should be included as well as how it should be structured. The politicians who made the decisions about how and when the curriculum would be enacted were essentially traditionalists with respect to education and wanted to perform what Ball (1995, p.87) calls '*cultural restorationism*'. From a curriculum analysis perspective (Posner's (2004) set one and two), there were tensions with respect to the situations that resulted in a curriculum and how it was documented. Politicians decided that a curriculum should be developed, science educators decided on the content, within a structure devised by politicians with an eye on making schools and teachers more accountable.

The science education community was empowered by Government to devise its 'ideal' curriculum. This allowed educational influence to take precedence over the political influence. The education community was given almost free rein to dictate the content of science education from age 5-16, something that had never been done before. The idea was to create a 'curriculum of consensus'. The problem, an inherent flaw in such an approach, is that the full corpus of scientific knowledge is far too big to teach and the competing interests of different subjects, disciplines, professional subject associations, employers etc. resulted in a very complex content heavy curriculum that was unmanageable and not deliverable in schools. While this period had within the curriculum a good view on the NoS, a lack of understanding within the science teacher community at large meant that it was unlikely this would be seen by many teachers as an essential aspect of science to teach (Donnelly, 2001). It could have been the basis of a coherent curriculum that finally brought the different disciplines of science together by explaining the structures of science and its epistemology. It could have significantly aided scientific literacy. The organisational influences of delivering such a heavily content driven curriculum meant that it was virtually impossible for the curriculum to survive for long.

**Period two** – The failure of the initial science curriculum was perhaps predictable given the competing influences and the tensions of trying to satisfy the large number of potential stakeholders consulted. Soon after the 1989 curriculum launch, the Government begins to rein in the science education community and requires the content to be slimmed down. With respect to Posner's (2004) framework and set two, the revised curriculum for 1991, fundamentally changes the structure and organisation of the curriculum, which had been topic based. A small team of science HMIs revert to a more

traditional 'three sciences' model for the curriculum and the NoS is relegated to the Programme of Study. The political vision of a knowledge-based, 'three sciences' was delivered over the more child-centred inquiry led and integrated curriculum originally developed by educationists.

In curriculum analysis terms, the purpose of the curriculum is becoming clearer. The Government see the purpose of the curriculum still in terms of the need to produce an effective and trained workforce for the economic good of the country. More importantly, it now has a way of holding school and teachers more accountable using outcomes from the curriculum, measured by new tests at age 7, 11 and 14.

Politicians were exerting more centralised control over schools and teachers. The change of focus in the end of Key Stage tests, by Kenneth Clarke, is one example of overt political influence. The move from internal teacher assessment of children's progress with tasks designed to enable teachers to understand how well (or not) children were progressing in their understanding, to measures of performance of teachers and schools, via pen and paper national tests taken by children at key ages reveals that accountability, an emergent theme, was a dominant purpose of the curriculum.

**Period Three** – In this phase the curriculum content is reduced with the view of returning more 'content control' to teachers. In Curriculum analysis terms, this represents yet another change in the organisation of the curriculum. There is also a change in educational influence with control of some content being returned to teachers from what was content determined by unknown educationists.

The concept of the three sciences recedes again, so the political influence that specified a traditional 'three sciences' approach was lessened and educational influence over how science content is presented is returned to teachers.

The curriculum, in terms of its breadth of coverage, while not quite concept or topic based, is more 'clustered' with related ideas brought together, e.g. Environment, Earth and universe in the 2004 version; energy, electricity and forces in the 2007 curriculum. The NoS is still present in the form of HSW, but its importance, with respect to those teachers who had to enact the curriculum, was still not comparable to the transmission of knowledge of scientific concepts and skills in experimental science.

### **8.13 Summary of the analyses and conclusions**

This analysis has charted the various changes across 1988 – 2010. Ultimately, what this shows is that the struggle for a NC is actually a struggle of policy over practice. On the

one hand, the Government wishes to make schools accountable for what they teach and for the standards achieved. Their policies are geared towards this rather than scientific literacy or an understanding of the NoS. This is understandable. Government produces policy not in a systematic, ordered, even logical way. It can be chaotic and, with the potential for changes in Government every five years, continuity is rarely achieved. As Stone (1997) says, *'the essence of policy making in political communities [is] the struggle over ideas. Ideas are at the centre of all political conflict'* (cited in Greenhalgh and Russell, 2006, p.34) Evidence, facts and data are not at the heart of policy making. The idea of a single curriculum that would suit all children of all ages and ability was an 'idea', but 'facts or evidence' that supported the notion that the idea could work were absent.

Thatcher wanted a very small, core curriculum, but Baker's vision was much bigger and was a full set of curriculum documents across all subjects. The idea of educators in meeting this policy demand was different again. One lesson from this analysis is that while Government policy may not be ordered or systematic and can very much depend on ideological preferences of individuals and parties, turning over control to those who are the 'experts' will not always result in the 'perfect' curriculum. Despite the extensive evidence taking and the ideas of some of the best experts in science education, what was produced was overly complex and burdensome.

One key factor that controlled the curriculum was the examination system and the fact that, even for the so-called 'Double Science' examinations, they were still examining separate subjects. The SNC was independent of the examination system, but the exam boards had to cover the NC content in their syllabuses/specifications. The outcomes from the examination system are grades that 'measure' children's performance and understanding in different subjects. These grades enable children to progress to employment or further and higher education. One stated outcome from the SNC was improved scientific literacy – the question is whether the examinations test scientific literacy or science literacy. The difference being, understanding holistically what science is, how it operates, the key skills and processes (practical and thinking) including the key concepts versus knowing a body of knowledge and being able to carry out scientific investigations/experiments. As (Chang Rundgren and Rundgren, 2017, p.235) discovered through their Delphi study of civic scientific literacy in Sweden:

School science all too often gives students a picture of science in general as composed of a set of true, objective, and value-independent "facts" that have to be learned, cannot be questioned or discussed, and have little or no relation to the everyday world of the student.

The structure of the curriculum and its tests and examinations was more likely to measure science literacy rather than scientific literacy. The wider context - the implementation of league tables for teacher and school accountability - also increases the need to pass tests/examinations rather than improve scientific literacy and understanding.

In Chapter 9 the experiences of four science teachers who, as children, were taught under the SNC (in full or in part) are examined next.

## **Chapter 9**

### **Analysing the experiences of recipients of science national curriculum teaching**

This chapter analyses the transcripts of four semi-structured interviews. The purpose of the interviews was to gather data that informs responses to some of the research questions (RQ) as detailed in section 4.1. The interviews specifically addressed how the science teachers articulate the NoS (part of RQ4); how (or if) the NoS promotes coherence across the sciences (part of RQ4) and how different scientific disciplines are viewed by the science teachers (RQ6).

The analysis is provided under the headings of four emergent themes from a Thematic Content Analysis (TCA) of the interviews: memories/experiences of science; reasons for taking up science; descriptions of 'the scientific method' (TSM) and the language of science and its key terminology.

#### **9.1 The purpose of the interviews**

The interviews were designed to gain an appreciation of the interviewees' experiences of being taught science within the NC as well as their understanding of aspects of TSM and language associated with the NoS, which may also be informed by their formal and informal experiences of learning science, working as scientists or in science related jobs. These are relevant to the following research questions:

- RQ4 – does the NoS (as written into the SNC) promote coherence across the sciences?
- RQ6 – how are the different science disciplines viewed by science teachers?

The interviews cover a very small sample of science teachers. The experiences of the interviewees, each of whom had studied science during the period that the NC was in operation, are the main interest, rather than trying to gather empirical data to try and generate a generalised view or theory of their experiences that could be applied to other situations or contexts.

In the preceding chapters, a review of the research literature demonstrated that science teachers do not necessarily hold coherent and/or a complex understanding of the NoS and that experiences of learning about the NoS are not consistent (see sections 3.7; 3.9; 3.10; 3.11). Even where science teachers do have a good grasp of the NoS, this



does not always translate into effective science teaching or delivery of the NoS to children (Zeidler and Lederman, 1989; Lederman, 1999; Liu and Lederman, 2007a).

The science teachers interviewed will be subject to a range of influences that shape their understanding of the NoS, TSM and how they define scientific terminology. Some of this will be because of their informal and formal learning of science as children (e.g. their early memories of science in a home setting or within a primary or secondary school setting). Their views will be further developed by their post school learning of science within a Higher Education setting or working as a research scientist in industry or in an academic (university setting). Finally, their views may also be further refined and changed having trained as science teachers, by engaging with the SNC in force during their training. Overall their descriptions and how they demonstrate an understanding of the NoS, TSM and scientific language will be a complex interaction of personal, informal and formal acquisition of knowledge and understanding.

## **9.2 Interviewee descriptions**

### **9.2.1 Interviewee 1 – Isobel**

Isobel is a physics teacher with a degree in mathematical physics. She is a middle manager in a private school who has been teaching over 5 years. She worked in other industries before training to teach physics.

### **9.2.2 Interviewee 2 – Thomas**

Thomas is a biology teacher who originally trained as a chemistry teacher (to access an available training bursary) and is currently a Deputy Head of Science in an academy school. He also worked in other, non-science settings before training to teach.

### **9.2.3 Interviewee 3 – Sophie**

Sophie is a recently qualified chemistry teacher who studied neuroscience and had worked in academia before training to teach.

### **9.2.4 Interviewee 4 – Ellis**

Ellis is a chemistry teacher who studied biochemistry. He held various short-term jobs, prior to teacher training, none related to science or his degree.

## **9.3 Interview analysis**

As described in Chapter 4, the interviews were analysed using a thematic content analysis approach. This generated a number of themes, each of which provides evidence for an understanding of how experiences of science have contributed to the interviewees' views and understanding of science more generally. The themes were related to the

analysis of the NoS themes evident in the various SNC documents as well as relating to aspects of the research questions.

Underlying the interview analysis are questions from Posner's (2004) framework for curriculum analysis. As discussed in Chapter 4, given that this case study is looking at a series of curriculum variations from a historic perspective, it is not possible to fully explore Posner's set three, the curriculum in action. It is possible, however, to infer from the interviews of the interviewees what their experience of the curriculum was during this period and to infer how this may have influenced their understanding of science as they proceeded to study above and beyond the curriculum. From the various questions that Posner poses within his third set (Posner, 2004, pp.21-22), the following is pertinent and relevant to the analysis of the interviews:

To what extent will the curriculum be consistent with and appropriate for the teachers' attitudes, beliefs, and competencies?

It is not possible to know what the attitudes, beliefs and values was for those teaching the early curriculum to the interviewees. What it is possible to infer is something about the attitudes, beliefs and values the interviewees - who are all currently science teachers - may have towards the teaching of science today.

Thematic content analysis of the interviews led to themes derived from the memories, reflections, knowledge and understanding of the interviewees. These themes are summarised in table 9.1. Each interview section has links between the emergent theme (which is derived from the analysis), the themes as derived from the SNC and NoS themes (see table 6.1) as well as to the parts and sub-parts of the research questions.

The six main themes in the table below represent the key themes from the interviews. Other themes, such as the complexity of scientific language and its effect on understanding (by children or the general public) also emerged but these were not dominant themes and have therefore not been included in this analysis as they do not directly relate to the research questions.

Table 9.1 Themes derived from the thematic content analysis of interviews.

Interview section	Emergent interview theme	SNC NoS theme	Relationship to research question
Early memories of science	Scientific Inquisitiveness	<b>(A)</b> Human endeavour	<b>RQ3</b> – delivery of aspects of the NoS in the national curriculum for KS 1&2
Memories of secondary school science	Cultural Heritage of science	<b>(A &amp; F)</b> Human endeavour and social contexts	<b>RQ3</b> – delivery of aspects of the NoS in the national curriculum for KS 3&4
Reasons for studying science	Utilitarian science	<b>(B, D, E, F)</b> Science as a continuous process, Reliability, Testing theories, Social Contexts	<b>RQ6</b> – how different scientific disciplines are viewed
Organisation of school science	Organisation of school science	N/A	<b>RQ3</b> – incorporation of the NoS into the science curriculum
Understanding ‘the scientific method’	Confused views of ‘the scientific method’	<b>(D, E)</b> Reliability, Testing theories,	<b>RQ4</b> – does the vision of the NoS promote coherence across the sciences?
The language associated with the NoS	Mixed meanings in key scientific terminology	<b>(D, E, F)</b> Reliability, Testing theories, social contexts	<b>RQ4</b> – does the vision of the NoS promote coherence across the sciences?

## 9.4 Interview section: early memories of science

### 9.4.1 Theme 1: scientific inquisitiveness

Interviewees were asked about their first memories of ‘doing science’ (either at home or in school), whether they recognised what they were doing was science and why it was memorable.

In three of the four interviews, the first memory of science was an activity in primary school. For example, Ellis recalled making a fruit battery – a simple activity using the acid in fruits, with different metals, wires, clips etc. to create a circuit to light a lamp. His identification of it as ‘science’ was not contemporaneous with the activity but was made with hindsight. In response to the question, ‘do you remember doing any primary science?’ he responded:

**ELLIS:** Not really, well, yes, we did but I don't know if I knew it was... you know what I mean, you do stuff and, like, it's sort of only after when I think about it that I see... perhaps, they... no, well I guess it was some science

**JDW:** What was it you were doing?

**ELLIS:** Ah, yes, well we were making batteries with fruit and things.

**JDW:** Oh, right, so stuff like...

**ELLIS:** I remember there was also a potato clock – I've done that in secondary, when I did my teaching practice at school X. I remember doing it with year 7 or 8? I think it was year 7, but I'm not that sure...

**JDW:** OK. But you did it yourself in primary...?

**ELLIS:** Yes, it was just a fun thing to do. I remember the teacher was quite excited... Miss F... she was great, I really liked her class...

(Ellis: interview transcript)

Ellis trained to be a science teacher in 2012, four years prior to the interview. He would have carried out the fruit/potato battery experiment around 1996 in his primary school. Sixteen years later, he was teaching this in secondary school. The place of some aspects of primary and secondary science teaching have not changed, or could be said to have stagnated, even regressed, as the same material is being taught and duplicated in primary and secondary science. This is not uncommon as Braund and Driver (2005, p.78) describe, *'pupils repeat work done at primary school, often without sufficient advance in challenge and sometimes in the same context, using identical procedures.'* This approach by Ellis's primary teacher would be of the kind that Posner, in curriculum terms, would classify as an experiential approach, aiming to provide a real-life experience that was child centred. How it is seen through the eyes of the child may be very different. They would see such experiences as interesting – they may be inquisitive and 'wonder' or be in 'awe'.

One purpose of the SNC was to improve the teaching of science education in the primary curriculum. It was noted at the ASE annual conference in Birmingham in 1989 that such change was necessary. We were, at that point, at the 'bottom' of an international test of scientific knowledge across 17 countries, with only the Philippines achieving a worse result (Wilby, 1989). It was postulated that it may well take up to 30 years for any change to take full effect. The talk, given by Jack Holbrook, executive secretary of the

International Council of Associations for Science Education, warned that a lack of attention to science education would have knock on effects for those who would eventually become science teachers (Wilby, 1989). Ellis seems to typify what Holbrook was suggesting. Change is not necessarily apparent in Ellis's experience from the time he did primary science to the point when he became a secondary science teacher in 2012.

Ellis had identified the activity as 'fun' rather than as a learning experience about electric current. He clearly had respect for his teacher and an affinity for her, saying how much he liked her class and how '*great*' she was as a teacher (see above), though this was not discussed at length. That Ellis decided, only on reflection, that the activity was science is interesting. His teacher, although enthusiastic, may not have been a science specialist and would perhaps be looking to deliver science in a fun and engaging way using tried and tested activities. This was a 'hands-on' experiential approach whereas the curriculum was being presented in a much more fact driven way, as in Posner's first curriculum perspective, the traditional approach. The intent politically was a move away from 'progressive', experiential child-centred teaching. There was then a mismatch between curriculum intent and curriculum delivery.

In contrast, interviewee Thomas recalls his earliest memory of 'science' being a visit to his primary school by two people who brought a variety of insects and other small animals:

**THOMAS:** Earliest memory... yeah, umm oh, yeah, err... well yeah, I do remember in primary we had this person, well two people I think... and they came with like loads of bugs and insects and things like that. I don't know where they came from, but I remember the girls screaming a lot and the boys were... yes, I remember that. It was sort of like amazing. I had this stick insect and it was on my hand and crawling... yeah it was like so good... I remember thinking how slow it was but yeah.

**JDW:** OK, great, yeah, so you had this 'show' why do you think that that was 'science'?

**THOMAS:** Oh, yeah, well at the time I don't know... well at the time I suppose it wasn't science, well it is science, but I don't think I knew it was science. It was interesting and exciting, yeah and I guess we did learn about mini-beasts, but no, I guess I didn't think of it as science, but now of course, yes it was science, it is... I mean that's what you do in primary school isn't it, you do things, but you don't know that it's science or that... err it has a name like.

**JDW:** OK, great, great. So, when do you think you first thought about or heard about 'science'?

**THOMAS:** Oh, I... I don't know, um yeah, it's I don't know. I suppose when you think about going to big school, yeah you think about doing science then, yeah. That would be I think...

(Thomas: interview transcript)

The memory appears to be based on the novelty of the insects and the visitors, rather than being the result of any formalised experience of being taught science – the memory is only later defined as a memory of science rather than the link with science being formed contemporaneously with the activity. Once more, it is the 'fun' or excitement and the inquisitive nature of the activity that makes an impression. This is also, in Posner's terms an experiential, 'hands-on', child-centred approach. Thomas, at this point, was not taught under the NC. It was introduced the year following his time in year 6. As such, there was no requirement for the teaching of science to any set statutory order by his teachers.

Sophie could not recall any activities from her primary experience that could be associated with science. Her earliest memory was of secondary science. She reflected on her early education as being very much focussed on creative arts, dance etc. This is unsurprising given she recalled that her early life at home was also dominated by creative activities. Sophie could recall looking at leaves in school but dismissed this as being science:

I don't remember doing science at primary school. We had lots of like looking at leaves and things, but I don't remember it being science and my parents aren't scientists, you know, so I didn't do experiments at home I didn't have a microscope they didn't get me a microscope. (Sophie: interview transcript).

This is another example of hands-on experiential science work that was not seemingly secured by the teacher as 'doing science'. Sophie was born in the year the NC was put into place, so her whole experience of science within primary and secondary school was of NC science. It is most likely her own interests in creative arts drives and shapes her memories, but that no instances of 'science' can be recalled easily is interesting. It is poignant that a 'microscope' was mentioned as a reason why no science was done at home. This could be a view of science that, in order to 'do' science, you need specialist equipment (see theme 2 below). The lack of a microscope invalidated activities at home being scientific.

Isobel had been bought a chemistry set by her parents when she was in primary education, a key memory for her. She also recalled her father building a bird table and bird watching, but she dismissed this as being 'science' as it was only identifying birds

and *'because it's not in the curriculum, things like birdwatching and that, as this is not in the curriculum I don't (consider it as science).'* (Isobel: Interview Transcript). The curriculum content here is defining her concept of what 'is' or 'is not' science. From Posner's (2004) perspective this is an example of the curriculum being seen, from Isobel's perspective, as a traditional one, perhaps a behavioural one. She sees the curriculum as a vehicle to convey the facts concepts etc. of science or as something that develops skills that are measurable. Although the observation of birds in their natural environment is clearly a scientific form of activity, that it is 'not' in the curriculum has excluded for Isobel any idea that the activity carried out at home could be 'science'.

Isobel had been identified within her middle school as gifted and talented in science. Her teacher, Mr Q., provided extra support for her and gave her more advanced lessons in some aspects of science:

**JDW:** ... when did you first begin to think about science as a subject and realise that actually I'm quite interested in this, this attracts me.

**ISOBEL:** probably in year six we had Mr Q... one of the year six teachers. And we worked in a science lab and stuff and that's when the National Curriculum came in. And there were big sheets with levels on them and I knew I was better than the rest of the class and I felt confident.

**ISOBEL:** So, he taught me how to balance equations in year six and he didn't teach the rest of the class the periodic table and all of that.

(Isobel: interview transcript)

This was also at a point when the NC had just come into effect for primary year 6. Isobel was in a school system that was tri-phase and the school she attended had specialist science facilities that primary schools, which catered for pupils only to the age of 11, did not have. Isobel's reference to the *'big sheets with levels'* is an indication that in the enactment of the curriculum, assessment and the need to define children's progress in terms of levels was a dominant one.

The interviewees all recall the 'awe and wonder' – the fun and engagement aspect – in the primary setting, though this was not identified as 'science' necessarily and is only, on reflection, recorded as such by the interviewees. It is perhaps indicative of a time when the teaching of primary science was characterised by avoiding tactics from primary teachers charged with teaching science. Tactics included limited teaching of science, a lack of discussion of scientific concepts, simple practical work and systematic instructions (Harlen and Holroyd, 1997; Harlen, 2001). It is, however, closer to the

pedagogy of primary teaching generally, with a clear hands-on, experiential, more 'progressive' Deweyan approach to teaching and learning. Memories of first experiences within science at primary school were consistent across all four interviewees.

## **9.5 Interview section: memories of secondary school science**

### **9.5.1 Theme 2: cultural heritage of science**

Thomas, who would have entered secondary school in the year that the NC came into effect, had memories of a neat and tidy lab run by a strict teacher who liked everything cleaned and in its proper place. At this point, his science teacher would have been coming to terms with the new curriculum and new GCSEs, as the main mode of assessment at 16, with the demise of the old O level and CSE examinations. His experience as a teacher would have been under the old regime of science education with multiple syllabuses, separate sciences and a range of lower school science courses.

Sophie, who had no recollections of primary science, recalled Bunsen burners as her first experience, as did Isobel (though this was during her time in a middle school). Isobel could not fully recall if she had used Bunsen burners in the primary phase or during middle school year 7 or 8.

Ellis's first recollections were of dissection in secondary school, but this was quickly followed by a memory of the Bunsen – he elaborated by saying that he recalls being told by Miss F. (his primary year 6 teacher) about Bunsen burners. He also related this to the stereotype of the 'mad professor':

**ELLIS:** I remember the Bunsen in secondary – we were all excited about that, I remember our teacher... Miss F. telling us about the Bunsen and we all thought it was mad science stuff, you know, like the mad professor in the lab.

(Ellis: Interview Transcript)

His memory is typical of introductory science lessons for secondary schools in the 1980s. He recalled drawing a Bunsen burner and recounted that he did not enjoy that. Ellis had been given a chemistry set for his 10<sup>th</sup> or 11<sup>th</sup> birthday which he felt supported his enthusiasm for chemistry:

**ELLIS:** Yes, indicators – doing acids and things – that's what I really liked as it was chemistry. I had a chemistry set at home – it was for my birthday I think I was about 10 or 11 can't remember now...

**JDW:** OK so your parents encouraged you?



**ELLIS:** Yes, my dad, well my stepdad, was good he was always buying me sciencey (sic) things for birthdays and that.

**JDW:** Was he a scientist?

**ELLIS:** No, he just worked in an engineering firm. (pause) He wasn't an engineer, he just worked there as a fitter.

(Ellis: interview transcript)

The memories of secondary school science for the four interviewed science teachers had similarities and subtle differences. The start of secondary science with an introduction to the Bunsen burner is a clear indication of Posner's (2004) traditional curriculum approach, the transmission of the 'cultural heritage' of the subject of school science.

For secondary school, the Bunsen burner as the introduction to science was an iconic image of science, along with test tubes, conical flasks and tripods. A standard lesson to 'embed' this cultural heritage revolved around drawing the various common pieces of apparatus. Research carried out in the mid-1980s, recording children's first experiences of science in secondary schools in Wales (Delamont *et al.*, 1988) confirms that such activities were commonplace. This type of lesson in the first year of secondary science is something that I recall from my own transition from primary to secondary school in the early 1970s, as well as being encouraged to do such lessons as a new teacher in the mid-1980s.

Science is presented as a specific type of hands-on activity, but it is experimental rather than experiential. Experiential learning involves the construction of knowledge and understanding from activities (usually 'hands-on'). These activities may not follow a strict procedure, whereas experimental science is rigorous and conforms to strict protocols. This view of science conforms with Posner's traditional curriculum.

Curriculum reforms of science in the 1980s and 90s were more about how the curriculum was managed, in this respect it is part of the organisational thread that is emerging from the case study. The reforms did not address the science content, other than some rearrangement of ideas and reduction of content. Progression was set out as simply a linear progression in learning scientific concepts (the levels Isobel recalled). Who authored the content, how it was put together and conceived and whether it had any underpinning conceptual framework was unknown. There was also the belief in primary education that 'hands-on' experiential science was the most effective way of teaching

the concepts (Sharp and Grace, 2004), a view supported by the experiences of the four interviewees here.

## **9.6 Interview section: reasons for studying science**

### **9.6.1 Theme 3: utilitarian science**

If we look at why the interviewees studied science beyond the statutory period, then why they decided to take up science as a potential university course and career option, we find a different set of memories and experiences. Schools and teachers prompt some of these, but they are also prompted by an intellectual curiosity that is more related to the NoS. These experiences and recalled memories provide evidence for the educational thread of the case study.

Isobel was motivated by wanting to know ‘how things worked’. She was good at mathematics, but wanted to do more than just study maths, she wanted to apply the maths she knew. She had taken all three science disciplines for A level but chose to continue her studies in physics because of the mathematics element. Her reasons for studying mathematical physics rather than experimental physics was related to her school experience:

I didn't like practical at school as it never worked, I never got  $9.8 \text{ (m/s}^2\text{)}$  for it or anywhere near it more like  $11 \text{ (m/s}^2\text{)}$  for acceleration due to gravity and I just thought it was rubbish.

(Isobel: interview transcript)

Isobel had an issue with ‘theory’ not being consistently ‘proven’ by experiment. She would have preferred the curriculum in Posner’s terms to have been a traditional one. For her, the transmission of concepts, principles, laws and skills was important. That said, Posner’s third approach, the structure of disciplines, would also have suited her as this was about the development of intellect and she clearly had an intellectual curiosity with respect to physics.

Sophie’s motivation for studying sciences stemmed from wanting to know ‘how people think’. Her interest revolved around human aspects of science and were reflected in her choices of sociology and psychology at A level. For Sophie, Posner’s (2004) fifth approach to a curriculum, a constructivist approach, where children construct meaning from the curriculum seemed to be important:

I did sociology GCSE and became interested in how people think and how will that affect us, so I was more interested in the human aspects of science and human interactions? So, then I chose A (level) psychology. I wanted to do

psychology GCSE, but my school didn't offer it. That's why I chose psychology A level. Umm... and I'd become interested, I don't know how, in neuroscience about fourteen I was going to be like a neuroscientist.

(Sophie: Interview transcript)

Ellis was also fascinated by how things work and that was a motivation for him to study sciences, the working out what was happening when different chemicals react was important.

Although three of the four being interviewed had experienced all their school science education after the imposition of the NC, it is clear the enacted curriculum needed to meet quite diverse needs. The 'form' of the curriculum, as Posner (2004) describes it, i.e. traditional, behavioural, constructivist etc. will have an effect on how children and teachers interact with the curriculum. The intended written curriculum was more geared towards a traditional form, where the content is specified and the 'instruction' to teachers is that 'pupils must be taught'.

That all the interviewees were successful in their curriculum and university choices, ultimately being awarded science degrees, could be an argument that their experiences of NC sciences did not necessarily have a detrimental effect. It is more debateable whether the curriculum positively aided their choices or progress in science.

## **9.7 Interview section: organisation of school science**

### **9.7.1 Organisational issues of the curriculum in a wider context**

There was a general concern over the introduction of the NC that exemplifies the organisational thread within this thesis. The Headteacher's union, the National Association for Head Teachers (NAHT), expressed concerns over the speed of introduction and the lack of training for staff, especially with respect to the assessment of the curriculum. The Government, in response, claimed adequate provision financially had been made and that training for staff was the responsibility of the LEA (Tytler, 1989). The initial proposal put to then Secretary of State Kenneth Baker in 1987/88 was sent back for revision as it included plans for a 'short course' in science occupying 12.5% of curriculum time. Baker's hope was that the majority of children would take the long course. The first enacted curriculum requirement for science at Key Stage 4 took 20% of the curriculum time in return for a double science GCSE qualification (Tytler and Broom, 1988).

### 9.7.2 Theme 4: organisational issues with science

All the curriculum proposals were predicated on either the short or long course which, as mentioned above, still left issues for those who wanted to offer triple science:

**ELLIS:** I did separate sciences; I was in the top stream...

(short time break)

**ELLIS:** Yeah, well, yeah, I did the separate sciences – we had to do a session after school. I wasn't happy, but my parents wanted me to do that...

**JDW:** What about you? What did you want?

**ELLIS:** Well, yes I did enjoy science and I'd made my mind up to do that at A level if I could, so yeah, I guess, yeah, I wanted to do it, but at the time, we had to do all the science lessons, but also an extra session after school on a Tuesday... a bit of a pain as I enjoyed sports and some sports clubs also ran on Tuesdays so I couldn't do them in year 10 and 11.

(Ellis: interview transcript)

Ellis was recognised as more able as he was in the top stream within his school and a combination of parental and school choice seems to have resulted in him taking the triple sciences, though as he admits, he did enjoy science. Despite this, there was some resentment over the extra timetabled classes.

Thomas had a stronger idea of his direction within science at school than Ellis. He knew that he wanted to study marine biology and took all three sciences at A level. He also took AS mathematics as well as A level mathematics. He recounted that his physics teacher was not keen on the double science award as an entry to A level. Statistics show that the percentage of students taking two or more science subjects at O level/GCSE had more than doubled from 41% in 1975-78 to 86% in 1997 (Bell, 2001). This increase was happening despite teachers' reservations over double science GCSE as an appropriate grounding for A level sciences (Macfarlane, 1993; Woolnough, 1994). Teachers' reservations are borne out to a certain extent, e.g. research by Gill and Bell (2013) determined that a predictor of physics uptake was a combination of separate science study in physics along with strong mathematics – what Thomas's teacher was arguing for in him.

A factor affecting the uptake of sciences at A level would be how children determine the value of studying sciences for future career aspirations. Thomas wished to study marine biology and was initially interested in an academic career and pursuing a PhD in that

subject. Sophie chose sciences over languages (despite her linguistic abilities) as *'I kind of thought, well I can make money as a scientist'*. Having achieved her goal, she reflected that in fact *'I've realised this isn't true'*. (Sophie: interview transcript). These factors are supported by the work of Bennet *et al* (2013) who found that students often made a proactive choice, especially in high uptake schools, as they contemplated their future careers. These responses provide evidence for the educational thread – how teachers or children see the study of a subject (or subjects) as educationally necessary for future employment or progression. In contrast, for Isobel, her choice was guided more by a love of mathematics and the intervention of a teacher who recognised her ability in science. This took her beyond the curriculum requirements and it was apparent that she saw it also in terms of employment opportunities.

## **9.8 Interview section: understanding 'the scientific method'**

### **9.8.1 Theme 5: confused views of the 'the scientific method'**

The idea of 'the' scientific method is pervasive within the sciences (McPherson, 2001; Williams, 2008a; Kosso, 2009; Tang *et al.*, 2009). All those interviewed recognised the phrase 'the scientific method', though their explanations of what it means, or how it is defined, varied.

Isobel, the mathematical physics graduate, was unclear on aspects of the TSM. She saw it as a mix of having ideas to investigate and confirming these with data as well as building up ideas (theories) from observed data. When she was asked about TSM – *'did she think that we start with ideas and look for evidence or start by gathering data and develop theories and laws from that?'* – her response was that it was *'a bit of both'*. To try and formalise this, the follow up question asked about inductive and deductive thinking/logic. Neither term was familiar to her. When a brief definition of each was given, Isobel thought that most science was probably inductive in nature.

Sophie had a clearer view of TSM and articulated in the following exchange:

**JDW:** OK so what do you think are the methods we employ to answer scientific questions. Like a good scientific method.

**SOPHIE:** Yeah having like a prediction and hypothesis. And then repeating results. Make sure there's no bias, so randomizing. Umm Looking for anomalies and trying to explain them like knowing if your results aren't correct it's important to know why they aren't correct. I mean that is. Yeah repeat some results using Yeah. Using stats appropriately.

(Sophie: interview transcript)

Sophie's own conception of the scientific method was guided or influenced by her work as a research assistant to a psychiatrist:

**JDW:** So, do you think that there is a universal scientific method. Or do you think the methods vary according to the discipline you're working in?

**SOPHIE:** I don't know, I've only really worked in a... strange areas, very related areas. Yeah, and the method has been very much the same. I don't know but the psychiatrist I worked for would say 'I need some results like this, how can we test that'. He would think more what's his story and then try and fit a method to the story that he was interested in

**JDW:** That's (an) interesting way to look at it, so was he was sort of starting with, almost like, this is what I think the explanation is and now I need to...

**SOPHIE:** ...Figure out how I can test that, Yes, I have to test. Yeah and get the results that will prove that. Yeah that's what he... Which I don't necessarily think is very good method of being a scientist. His result is always informed by what his idea was at the end. So, we'd have quite a few arguments because I'd say I think we should have a more, you know, that can be one of your hypotheses, but we should also be testing these two other things because, that's your idea at the beginning which is it's an Idea you can test but that might not be the answer. So, we should be exploring other roots as well. So, I tend I think sometimes it's good to have that backwards approach he would drive his ideas forward. And sometimes I would find results and I'd be like oh this is really interesting he wasn't interested in that and wouldn't publish that side of things he would just gloss over it and just read the results of what his interest was.

(Sophie: Interview transcript)

What Sophie described initially was the hypothetico-deductive method, a common approach in psychology (Haig, 2014). It was her way of working normally. However, her experience of working with a scientist threw up some issues over how science should be conducted. There were obvious tensions in the way the scientist worked that concerned Sophie. She felt that determining the 'idea' from the start and gathering evidence to support that introduced a bias. She would have preferred to generate other hypotheses to test. This certainly set up some tension for Sophie who disagreed with this way of working, though she could admittedly see a place for such working.

Thomas went into some detail on theories, laws and evidence (see later), but when it came to assembling these for a 'method', his approach was the opposite of Sophie's approach:

...so that's how we do science, we get our evidence and we make up a theory... well no, we don't make it up, no it's not like it's 'made up' (air quotes)...we use the evidence to try and find a theory to fit the evidence.'

(Thomas: interview transcript).

Ellis had an interesting view of TSM and how this makes science a discipline different from others. In a section of the interview we had discussions about things like astrology and homeopathy. None of the interviewees, when asked, thought that either of those 'subjects' were true sciences. Ellis had the strongest reaction and defended his views by invoking TSM. In describing how science is conducted he said:

It's like you have to publish and to do that you have to make sure that you have... follow the scientific method otherwise your science would be rejected.

(Ellis: interview transcript).

Later, he was directly asked about TSM:

**JDW:** You've mentioned the scientific method a few times today, so what is that method?

**ELLIS:** It's how we do science; it's about coming up with an experiment to find out what you want to know. So, you start with a question then you design your experiment to try and answer the question. You do the experiment and see if you get an answer. But, it's a bit more complicated than that as you might have to change your experiment until you find the one that works. That's often what happens, you find that your experiment fails so you have to go back and try something different.

**JDW:** Right, right, so, when you design your experiment are there rules you have to follow?

**ELLIS:** No, yes, well not rules, but protocols – there are various protocols you have to follow for experiments and I suppose they are rules yes.

**JDW:** Yes, and do you do this in school with the children?

**ELLIS:** I suppose yes, we do, yes. But our experiments are not as difficult, and we don't get the kids to design them from scratch. But yes, they do sort of the same things. We teach them about variables and fair tests, we teach, teach, well... the fair test is about controlling the variables that's important.

**JDW:** OK, so independent and dependent variables?

**ELLIS:** That's it, yes, yes,

**JDW:** Is there anything else about the scientific method? How would you sum it up if asked?

**ELLIS:** (pause)... ok, um... yes well, it's like how you report what you've done, you follow the method and report that in your lab book your experiments that you do. So, it follows a pattern I suppose. You start with your hypothesis, then you list your equipment and have a step by step approach. It's important to think about your results as well, how you are going to record those and how you are going to display them. Then you have to analyse your results and finally discuss them and come to a conclusion. You'll also evaluate what you've done, you know like sources of errors, like and that, and so on.

**JDW:** So, the scientific method for you then is that plan of how you do and report your results of experiments?

**ELLIS:** Yes, that's it, yes.

(Ellis: interview transcript)

Ellis had a strong view that TSM should determine the reliability and validity of science. The key element for Ellis was the setting up of experiments predicting and dealing with variables as well as the concept of the 'fair test'. The idea of the fair test could have resulted from his experiences in primary science as this was a common way for non-specialist teachers to deal with variables (Turner, 2012).

In the early 1990s, the NC had a structure for the first Attainment Target (Sc1) where four strands had to be assessed by teachers for the coursework element, hypothesis and prediction, observation, interpretation and evaluation. These were difficult to assess within the context of a single 'investigation'. This led to the assessment of practical science skills through a series of investigations that concentrated on one or another element.

In a review of the NC by Liverpool University (Hutchison and Schagen, 1994), it was noted in a Guardian newspaper report that:

Sc1 started to condition the teaching of experimental science. Classroom teachers noted that many pupils equated hypothesising with guessing or predicting what the teacher was expecting. They then ignored their experimental findings and falsified their results (Sweetman, 1994, p.11).

This led to a major change in the structure of Sc1. The changes marked a shift in the curriculum that moved away from science as experimental, something that follows a set of rules or protocols. The new curriculum shifted more towards the practical skills being predicated on inquiry-based teaching where the skills could be assessed without being



part of a full investigation but could more easily come from day to day teaching of concepts and classroom-based experiments.

### **9.9 Interview section: the language associated with the NoS**

The use of scientific language in teaching is important and it is an issue when it comes to children engaging with and understanding science (Wellington and Osborne, 2001). If science graduates teaching science cannot themselves articulate clear definitions of key terminology, then the use of scientific language in science teaching and learning is bound to have problems. The issue of the language of science (as in the complexity of scientific terminology) was seen by the interviewees as a barrier to understanding science. As Thomas noted:

people like always say science is like another language and we always use big words and things like that... So yeah, language yeah it can be a problem I think.

(Thomas: interview transcript).

Sophie placed part of the blame for this on scientists themselves saying:

I think its scientists get so far into the science mind-set in using that scientific vocabulary and pitching at a certain level for colleagues. They're not very good at just breaking it down to the most important key points that people need to understand

(Sophie: interview transcript).

In their teaching, the interviewees recorded that they used key words in class as well as using the etymology of words to break them down into constituent parts to enable children to understand them.

The terminology used in science, e.g. law, theory, hypothesis, principle, fact may seem at first sight uncontentious. Published research (Williams, 2013) has shown that far from being well understood, these terms are variously defined and do not represent a common basis for 'talking science', for example, when a person says, "*I have a theory about that*", the phrase could be interpreted as coming from a scientist, a lay person or perhaps a police officer/detective. Each of these would use the term in a slightly different way. The fact that the phrase may have been said by a scientist, or a science teacher, does not necessarily convey a specific meaning to children.

A strict definition of terms is not easy; different textbooks, different disciplines will define the terms slightly differently. Added to this is a potential for a vernacular definition for

some of the terms or alternative definitions that are context dependent. For example, 'theory' will have a vernacular definition that could mean a guess or a hunch (e.g. within the context of a police crime). 'Law' also has a legal definition as well as a scientific one. What a 'fact' is, can also prove difficult to define in a scientific sense.

### **9.9.1 Theme 6: mixed meanings in key scientific terminology**

#### **9.9.1.1 Theory**

A theory in science is explanatory. It is, at its simplest, an evidenced explanation of a natural phenomenon. To an extent they are 'ideal' explanations as, in real life the experiments we do and the observations we make do not always match our ideal explanation (the theory), a situation that drove Isobel to study mathematical physics rather than experimental physics. In science, a theory is not a guess or an untested 'unproven' idea. There is a relationship between theories and laws, but that relationship is not hierarchical. A common misconception, in part reflected in the evidence below, is that a theory becomes a law once 'proven'.

In the interviews, a question asking for a definition of a 'theory' produced the following responses:

OK well, yes, a theory is something that we know in science works but we just haven't quite proven it yet, so we call it a theory

(Ellis: interview transcript).

I think it's usually an Idea with some evidence for (it) that hasn't necessarily been proven right

(Sophie: interview transcript).

In both cases, there is a link to theories and the idea of not yet being 'proven'. While it is the case that, within science, all ideas including theories are provisional, theories have a status that is more than just an 'idea' as Sophie hints at.

Thomas, on the other hand, provided a definition that was closer to the definition of theories as explanations of natural phenomena:

a theory is like what I just said, so it's a way of showing what's happening in science, so you have a theory and you test it to see if it's correct. So, a theory... err it's the way... it's like. Um A theory is something that helps us understand what's happening, but we haven't found out exactly what's happening, so we carry on testing the idea to see if we can learn more.

(Thomas: interview transcript).

Isobel, as a mathematical physicist who avoided (deliberately) the practical side of Physics during her degree had a slightly different take on theories. She noted that:

Kinetic theory is something that works but it's not come from absolute, it's come from some ideas and it's used to explain what's happened as an explanation, but kinetic theory doesn't work that well it only works on an ideal gas that does not exist.

(Isobel: interview transcript)

This is interesting as she looked at theories as aspects of science that did not 'work' as such in real life. She went on to explain how her experience of practical experiments in Physics classes was one where she failed often to get the 'correct' answer (section 9.6.1), that is, the one the theory would predict. The idea that theories are tested is a common one with all four interviewees. Here I am detecting a conflict between an ideal that Isobel has of science within a positivist framework and real life. She almost wishes that science in real life imitated the predictions of theory (the mathematical theories so common in physics) so that an experiment will provide the same answer as that calculated via theory. Acceleration due to gravity is calculated as an average of  $9.81\text{m/s}^2$ . If we think about gravity and the Earth logically, we cannot have a single value for acceleration due to gravity as gravity values vary over the surface of the Earth. The Earth is an oblate spheroid, so, at the equator it is 'fatter'; there is a greater mass of rock beneath your feet hence your weight will be slightly greater at the equator than at the poles where the mass of rock beneath you is less. Gravity will also alter due to, for example, large masses of iron ore buried in the lithosphere – for example, your weight will increase slightly if you are standing on the surface of an iron mine. The value that Isobel wanted so much to obtain by experiment was never going to match the averaged number that 'theory' predicts. Critical thinking in science and the application of forms of logic would help here. Understanding the NoS would potentially mean a less positivist view of science with definite answers analogous to mathematical proofs.

Here we see an interesting comparison between mathematics and science and the difference between theory and theorem. A theorem in mathematics can be proven to be 'true' or 'false'. Truth, therefore, is part of the mathematician's vocabulary. For the scientist, truth is not the objective of the 'proof' of a theory. Isobel's choice of a mathematical physics degree over an experimental one is a choice of a positivist view of science over a post-positivist, critical realist view of science.

### 9.9.1.2 Hypothesis

When dealing with 'hypothesis' Ellis equated this to a scientific question or just asking a question, '*...well, yes, a hypothesis is a question I suppose it's just another way of saying you are asking a question, but in science the language, you know...*'. He went on to qualify this saying, '*...you need to be able to predict what the answer could be otherwise it's not a good hypothesis*' (Ellis: interview transcript). However, he then expanded on this by saying:

Well, hypotheses are like theories. They aren't proven they are what you want to prove or test I suppose, so they are not facts, but things to experiment with until you find the answer. I guess they aren't really theories; they are just guesses, I suppose (short pause), I think.

(Ellis: interview transcript)

There is clearly confusion here and attempts to relate hypothesis to theories, which would be correct, but the link is being made between hypotheses and proof. The idea of the hypothesis as a testable scientific question is not quite explicit.

Sophie had a much more sophisticated idea of the definition of hypothesis:

I always teach this (to) the students, that a hypothesis is an idea you can test, and a prediction is...um...you've got some scientific information and you've got an idea of what will happen and you want to test if it will occur as you think it will. So, hypothesis, I teach that it's more of an idea that you're going to test, your predictions more based on fact, it's right.

(Sophie: interview transcript)

Thomas likewise thought of hypotheses as testable ideas:

well that's to do with any experiments you do, so you have a hypothesis and then you do your experiment... and you find out if you are right or wrong.

(Thomas interview transcript)

He also, later, linked the idea of hypothesis to theories, i.e. hypotheses can come from theories as a means of testing them.

During these exchanges we are seeing part of the natural selection idea of knowledge, that is, the testing of ideas and the rejection of some ideas that do not 'fit' the explanations and the acceptance of others, or evolutionary epistemology (Bradie and Harms, 2001). In some ways what we are seeing here is the notion that ideas will have

some form of intrinsic 'survival' value. The better the hypothesis or the idea the more likely it is to survive. A poor hypothesis or idea will not be fit for purpose and so will become extinct and will not survive. There is also another post-positivist element seen here in the idea of constructivism. The ideas being put forward are constructivist – as teachers they are encouraging children to build upon their knowledge and understanding and produce better explanations for the phenomena they are investigating.

### **9.9.1.3 Law**

Sophie, following on from her ideas of hypothesis and theory, created a link between these and the concept of a law in science:

I suppose a hypothesis is something that you're testing that's an idea. A theory is an idea or something that's been tested or is or has been shown maybe and a law has usually been proven or works every time.

(Sophie: interview transcript)

Her understanding was of a hierarchical link between hypothesis, theory and law. The implication here is that one could lead to the other depending on the level of 'proof'. In essence this is a constructivist view of knowledge and understanding. In reality, it is incorrect. A hierarchy of ideas from hypothesis to theory to law is not how science 'works'. In short 'law' and 'theory' have two different functions in the NoS: theories explain, laws describe.

### **9.9.1.4 Principle**

A principle in science has an interesting status. It is similar to, but not exactly, a 'law' (see above). It is similar in that it describes something rather than explaining it (which is the role of a theory), but more than that, it is a set procedure which can be followed to demonstrate something found in the physical sciences. For example, Archimedes principle states:

That any-body completely or partially submerged in a fluid (gas or liquid) at rest is acted upon by an upward, or buoyant, force the magnitude of which is equal to the weight of the fluid displaced by the body. (Anonymous, 2016a)

It is possible to 'do' this, in the form of a simple experiment, from the information given. It demonstrates the law of buoyancy, but it is not a 'law' as such. In Physics teaching it is an 'old' tried and tested experiment.

Three of the four interviewees provided a definition of a principle that varied between being a law, or more like a theory. Again, there were hierarchical connotations where the

principle was deemed better than a theory but not quite a law. None of the four were clear on what a 'principle' was:

Yes, principles, yes. I don't know, they aren't laws obviously because they would be called a law, so I think maybe they are... I don't know, that's a trick question. Yes. I'll have to think about that one (Ellis: interview transcript).

Principles. I'd say it's more like oh. I don't know, but I'm thinking it's more like theory. Then it's principles and usually... I think between theory and law, like it's been tested. It is really tricky maybe that's why you don't think about these things at Key Stage 3

(Sophie: interview transcript).

Within the discussion of laws and principles two issues arise that are pertinent to how the respondents view science. There seemed to be a sense that their view of these terms was hierarchical and that the higher the status the more confident they could be that what was being discussed was more secure knowledge and understanding. It was, in effect, more reliable.

### **9.10 Summary**

From the individual interviews, themes emerged such as scientific inquisitiveness. Each person was able to recall aspects of science from within their early school memories or from home. The impact of the SNC was also evident, for example Sophie recounting how she recalled the introduction of the SNC and 'levels' being used which indicated to her she was quite good at science. This is an example of the organisational influence – the memory being of the levels rather than of the activities etc.

There is also the repeating of work (rather than revisiting, with an increasing conceptual difficulty, via a spiral curriculum) that was experienced by Ellis who, having investigated 'fruit batteries' in his own primary experience was also teaching the same content as a secondary science teacher. Issues and questions arise from this about the organisational and cultural heritage of science. Questions such as, whether there is a lack of understanding of the core content of primary science by secondary science teachers and, whether we teach certain concepts or do key experiments in science just because that is the way we always have done these things. Hands on science was a common memory of early science for the interviewees, such as Thomas's memory of the bug and insect show that came to his school. Secondary science memories clustered around the use of the Bunsen burner – another example of a traditional curriculum approach that delivers the cultural heritage of science as well as utilitarian science, getting to know and use science equipment.

The utilitarian aspect of science was summed up by Sophie, who made her degree choice in part on the notion that scientists can earn more money, though she admitted that this notion might be a false one.

In the case of Ellis, there was a commonly experienced dilemma, which as a science teacher I experienced many times, over how to deliver the three separate sciences in a crowded curriculum. His experience of being required to undertake extra teaching and that it was reserved for the more able children illustrates just one of the major organisational problems schools had. The curriculum content was very high. This was recognised in the draft and first enacted curriculum of 1988-89. It resulted in a reduction in the content with further reductions being made in subsequent revisions (see chapters 6-8).

There was some confusion over the meaning and interpretation of 'the scientific method' (TSM) by the interviewees. Sophie had one of the clearest ideas of what it was and had been guided through working with a psychiatrist. Others had mixed and erroneous views and definitions. One misconception was that TSM was simply how you 'do' and report experiments with Ellis saying *'it's like how you report what you've done, you follow the method and report that back in your lab book, the experiments that you do.'* This clearly exemplifies theme 5, confused views of 'the scientific method'.

Theme six, mixed meanings in key scientific terminology was exemplified by the various definitions some partly correct others not correct of different terms that are essential to an understanding of the NoS. Words like 'theory' where, for example Ellis presents this as something *'...we just haven't proven yet'*, which was similar to Sophie's definition.

Other terms, such as 'law', 'principle' etc. were not well defined and this raises a serious issue in relation to the understanding of the NoS. A key aspect of that is knowing and understanding the distinction between laws and theories and the fact that science is never absolute or certain (see section 1.4).

Two of Posner's (2004) approaches to the curriculum, the traditional, which is about the transmission of a subject's cultural heritage conveying the facts laws etc. and his third approach, the structure of disciplines are evident within the final two parts of the analysis, the descriptions of 'the scientific method' and the terminology of science. The problem here is that neither TSM, nor many of the key terms that are central to the NoS are well understood or articulated by the interviewees. It is worth noting here that just four science teachers were interviewed. It would be wrong to generalise from this. Research, noted in Chapter 1 and 3, on teachers understanding of the NoS and research on the

understanding of key terminology indicates that this is a wider problem and the four interviewees simply reflect a more general situation. This being the case, the cultural heritage (as Posner (2004) defines his first curriculum approach) of science, the facts, laws, theories etc. is not well served necessarily, simply by the curriculum experienced by the four interviewees across their education experiences. It must be recognised here that there is a great deal of complexity in both uncovering and documenting the experiences that will contribute to their overall understanding of the NoS and TSM. This will be the case for children as well as their teachers. With TSM there appears to be a confusion and conflation with the protocols and skills of science and a lack of understanding of the logic of science and how scientists think or produce their explanations of natural phenomena. In this case study, it is apparent that the idea of different disciplines applying different methods is also not clearly understood by the interviewees.

The analysis of the interviews provides evidence for the main problems identified by the curriculum review. There is a lack of coherence at a macro and micro level in the SNC. The curriculum itself does not have a consistent well-articulated approach, which should have been clearly communicated to teachers. This resulted in an inconsistent delivery of the curriculum and the received curriculum was then likely to be reinterpreted by the children. This is something which could be addressed during ITT, but the demands on ITT to cover not just how to teach, but also fill in gaps in subject knowledge, well as behaviour management etc. means that curriculum coherence is not a priority.



## **Chapter 10**

### **Discussion, Findings and Conclusions**

This case study has examined the educational, political and organisational influences on the creation of a national curriculum and, in particular, a SNC in England from 1988-2010. The case study examined the place and evolution of one key aspect of science education, the NoS within the SNC. It produced several findings that relate to the construction of a curriculum, how curriculum reform can affect the coherence of a subject and how it may have unintended consequences, such as undermining scientific literacy. It has argued that the shifting position and lack of prominence of the NoS in the evolution of the SNC was a lost opportunity to enhance the status of the NoS, the coherence of the sciences and scientific literacy, which is related in part to teaching about the inductive, deductive and abductive nature of scientific logic. In a broader sense, this case study provides evidence about the fundamental tensions in constructing a science curriculum, which makes its implementation more complex and, as a result, lessens the chance of a curriculum being successful in achieving the outcomes intended by those who construct and write the curriculum.

There are many tensions in education. In one sense, this case study is a study of those tensions – between politicians and schools, between curriculum designers and those who enact the curriculum, between teachers who enact the curriculum and the children who receive the curriculum. These tensions are not bilateral – they form a connected web of tensions that affect how policy is created, proposed, enacted, delivered, and received. The one unifying aim, commonly ascribed by science educators, to all involved, is the raising of standards. To say that this was the most important aim or priority for all of the ‘actors’ involved within the web of complexity that characterises how a curriculum is created and delivered would be wrong. Teachers teach for multiple reasons – to impart knowledge, to encourage children to enjoy the subject they teach, to enable children to achieve their full potential (however that is defined). Whether all these are ‘raising standards’ is debateable. When we add into this the fact that political influences have the possibility of dramatically changing every five years, as general elections are fought, won and lost, it is no surprise that coherence is lost or not achieved. Institutional practices and the various discourses that take place over how any curriculum should be implemented and interpreted will also affect approaches to the implementation of the curriculum to a greater or lesser degree.

## **10.1 The research questions revisited**

The research questions (section 4.1 & 4.2) were the drivers of this case study. In reviewing and analysing the curriculum to find answers to those questions, primary sources were used, that is, written sources of evidence (such as documents reports, draft and final curriculum documents etc.) created at the time the events took place. Secondary sources that analysed reactions to the primary sources were also used to inform and enhance the outcomes or answers to the questions. What follows is a summary of the answers obtained from this case study related to the six research questions.

### **10.1.1 What was the origin of the SNC and how did it develop over time?**

The SNC came from a wider political change to the education system. Its origin lay with a political recognition that a common core curriculum was needed. There were several reasons stated for a common core curriculum, these included a political wish to hold schools, and eventually teachers, more accountable. As detailed in Chapter 5, the period leading up to the implementation of a NC saw many reports and reviews of the curriculum, such as the Yellow Book (reviewed in Section 5.1.1) which was used by politicians to identify the need for change and who saw HMI as the mechanism for facilitating that change alongside monitoring the effects of change.

Critical to the origin of the NC and the SNC was Callaghan's Ruskin speech (see section 5.1.2) which made clear the political wish for a core curriculum. Additionally, there were questions raised about how the curriculum was delivered and how it was assessed. This marked a major turning point for state education. Politicians had historically been absent from discussions about what should be taught in schools, how it should be taught and the assessment of the taught curriculum, but after the Ruskin speech the so-called 'secret garden' of the curriculum, the curriculum content, was to be secret no longer. Politicians were taking on the role of head gardener, assisted by experts, to determine not just what was taught but also how the curriculum should be delivered and assessed.

The development of, and changes to, the curriculum over time (see Chapter 7, table 7.1) was intense in the first few years until the review by Dearing (1994) which prompted a period of no change from 1995 – 2000. Initially, the changes were dramatic and led to a move from teaching by concept to teaching by subject discipline. The curriculum that existed in schools until 1988 originated from the 1904 school board requirements for schools to teach subjects (see section 2.7). This list of subjects for schools was seen by some as socially divisive (Lawson, 1973; Wrigley, 2014). It established 'academic' subjects for those who were considered part of the elite and other, less academic, more

vocational subjects being suitable for the working classes (Goodson, 2005). In its earliest days, compulsory education was not seen as a mechanism for social mobility. The politician Robert Lowe is claimed to have stated that *'We do not profess to give these children [i.e. those whose parents cannot afford to pay] an education that will raise them above their station and business in life'* (cited in Wrigley, 2014, p.212). Social class divisions were reinforced in the curriculum with the advent of the 1944 education act, which structurally changed the school system to more overtly represent the prevailing social class structure. It made provision for Grammar Schools, Secondary Modern Schools and Technical Schools; the elite still had access to private schools. The curriculum on offer for science was often separate subjects within the Grammar Schools and integrated or general science in the Secondary Modern Schools. The move to a comprehensive system, initiated by the Labour Government elected in 1964, coincided with a move to the increased provision of general or integrated sciences. Separate sciences for those who wished, or were encouraged, to study science beyond 16 remained. There was, and to a degree there still is, a gender imbalance in the sciences, especially in the physical sciences (Carroll and Gill, 2017; Cassidy *et al.*, 2019). The physical sciences were also traditionally shunned by girls, but biology was less popular with boys (see tables 2.1 & 2.2). A move to implementing general science for all to the age of sixteen was also part of the political decision to introduce a common core curriculum in the form of the SNC in 1988. This required all pupils to study all science disciplines up to the age of sixteen. This was signalled in the government policy document that advocated broad balanced science for all (DES, 1985). To achieve this, children could study 'single science', 'double science', or 'triple science'.

In addition to the political changes and motivations for a NC, there was a move to ensure that children moving from one school to another were not disadvantaged through discontinuities in curriculum content. This was an educational consideration intended to help increase the uptake of the sciences at post-16 and at university level.

#### **10.1.2 What were the educational and organisational influences on its origin and development?**

Politically, it was felt that schools, teachers and the Local Education Authorities (LEAs) needed to be held to account for the outcomes achieved by children. This was a key message in Callaghan's 1976 Ruskin speech, also echoed by Margaret Thatcher's government in 1979 (see Chapter 5, especially section 5.5). The existing model of accountability was one of local accountability with schools answerable to the LEA. LEAs were created by the 1902 Balfour Act (see section 2.7) which gave them control over local state schools. This was a Conservative Government idea. Local elections decided

which political party controlled the LEAs. Thatcher was increasingly of the view that Labour councils dominated LEAs, of which there were many in the 1980s. This included the Inner London Education Authority (ILEA), who were seen by Thatcher and others as reckless in spending terms. Thatcher also had a view of education that was too progressive (see Chapter 5 section 5.4.2). Thatcher's mentor, also one-time Secretary of State for Education, Keith Joseph, supported and encouraged this view and they moved to relieve LEAs of many of their powers over schools. The NC and the SNC was one way, along with many other measures introduced in the 1988 ERA, of limiting the LEAs influence and allowing for more centralised control over the curriculum. This, coupled with tests at 7, 11 and 14, was seen as an effective way of holding schools and teachers to account, bypassing the LEA.

From an organisational perspective, the 1944 education act structured education provision based on the prevailing social 'class system' (section 2.7). The curriculum up to 1944 was first put in place in 1904. This curriculum remained stable (though the content for different subjects varied according to exam board). During the 1950s, there was a rebuilding programme for schools following the loss of many due to bombing in the Second World War. The introduction of tripartite selective education from the 1944 education act, saw the establishment of Grammar Schools, Secondary Modern Schools and Technical Schools. Technical Schools were fewer in number due to the costs of setting them up and the nature of the specialist teaching and teachers required (Bolton, 2012).

The 1960s saw a pivotal movement of political, organisational and educational influence. This came about when a newly elected Labour government required schools to plan for a shift to comprehensive education. Labour's plan did not include a legal requirement for LEAs to change their provision from a selective one to a non-selective comprehensive system. There was only a legal requirement to plan for change rather than effect an actual change. This allowed a few Local Authorities, who saw selective education as popular among their voters, to avoid the organisational change from selective to comprehensive education. Consequently, selective education is still in place in some regions (most noticeably Kent) and the '11+ test' is still a tool for academic selection. Some academies are now introducing 'grammar streams' that support the teaching of 'triple science' over the 'double science' provision for the majority of children and 'single science' for some' (Adams, 2017).

### **10.1.3 How has the NoS been incorporated into the science National Curriculum?**

The review of documentary evidence suggests that the first draft version of the SNC (DES, 1988b) had the most detailed and well thought out approach to the NoS (see section 6.6). It was contained within a complete attainment target (AT22). Even the revised SNC (DES, 1989), although modified, had a complete attainment target (AT17) for the NoS. At this point, the NoS was integrated into the intended curriculum. The approach to delivering the content, unlike the other attainment targets, was not that the NoS should be a discrete or independently taught AT, but that it should be delivered alongside the conceptual science content. The problem that arises here is that it assumed that teachers were sufficiently well versed in the NoS to be able to effectively integrate it within the rest of the subject content. The evidence from the review of the literature presented in Chapter 3 (section 3.7) shows that not to be the case.

With subsequent revisions of the SNC, the NoS lost its status as a full attainment target. It was still part of the programme of study and the intended curriculum still required that the NoS be delivered through the teaching of the content and concepts of science. The problem with this is summed up by Donnelly (2001, p.184): *'it's just human nature that if you have to assess certain things, those will be what they (i.e. teachers) will teach'*. The programme of study was a broad, overarching view of what needed to be taught. Teachers, however, concentrated on teaching the many statements of attainment as these were the items being formally assessed. The unwieldy nature of the curriculum, which was still overloaded with content, led to 'teaching to the test' (Donnelly, 2001; Boyle and Bragg, 2006). Over time, the NoS slipped in and out of the PoS and the ATs and metamorphosed from the 'Nature of Science' to 'Ideas and Evidence', then 'How Science Works' ending up finally as 'Working Scientifically'. Such changes to the overall description do not promote coherence, as there is a danger that each change in title could mean something 'different' to different teachers. There was also little explicit explanation for teachers in what these ideas meant, the danger being that the true meaning of the NoS could get lost in translation.

### **10.1.4 How is the NoS articulated in the science national curriculum and does this vision of the NoS promote coherence across the sciences?**

This case study reveals that many influences shaped the SNC from the status of the various science subjects to the delivery of the content e.g. moving from an integrated/general science approach to the more traditional three sciences with the delivery of facts, knowledge and skills being dominant.

The evidence also reveals that the initial conception of the NoS contained within the draft and first enacted SNC (DES, 1988b; DES, 1989) promoted a model that was consistent with existing conceptions of the NoS (see section 6.4). Although presented as a coherent attainment target, it was suggested that it was taught as an implicit aspect of the science content rather than an explicit concept. The literature reviewed in Chapter 3 within this case study (section 3.9 and 3.10) shows that generally teachers did not have a well-developed conceptual understanding of the NoS. Even when they did, it did not always transfer into their lesson planning and delivery. The lack of a well-developed conceptual understanding is also supported in the interviews carried out for this case study (see section 9.8). The NoS has the capacity to promote coherence with respect to the various disciplines of science. This is achieved by providing a sound epistemological and ontological basis for understanding the individual characteristics of different science disciplines. It requires first that teachers have knowledge and understanding of the NoS and that they can then assimilate this into their PCK (see section 3.10).

#### **10.1.5 How has the evolution and development of the science National Curriculum affected the NoS and its incorporation into science education?**

The establishment of the SNC led to unintended consequences for the NoS. NC subjects acquired status according to their position within the curriculum, e.g. science was a 'core' subject, geography a 'foundation' subject. The testing of the 'core' subjects and the subsequent targets against which schools (and teachers) were held accountable gave the subject content a high profile. Within the curriculum itself, the status of the content was enhanced if it appeared as direct 'statements of attainment' rather than as an overarching 'programme of study'. It was then inevitable, as Donnelly (2001) noted (section 10.2), that teaching to the test would take place based on the statements of attainment. The removal of the NoS as a full attainment target to the PoS would, in effect, downgrade its status. The lack of in-depth testing of the content would further dilute its importance (Jenkins, 1996; Rudolph, 2000; Donnelly, 2001). Such structural changes would influence how the curriculum was delivered (Jenkins, 2000).

The NoS was almost completely removed from the curriculum in 1991 (DES, 1991a; 1991b) but returned in various guises (as noted above). Coherent explanations of what these aspects of science were, that is 'Ideas and Evidence', 'How Science Works' etc. and why they were important in the teaching of science were not explicit (see Chapter 8, section 8.6). This left science teachers to construct their own meaning for the NoS. Evidence from the interviews for this case study show that the science teachers' construction of such meanings was neither complete nor consistent as their own

conceptions of the language of the NoS and TSM were incomplete (Chapter 9, sections 9.8 and 9.9).

The removal of the bulk of the NoS content in the 1991 revised SNC (DES, 1991b) into the PoS, meant that one aspect of the NoS, process skills, was singled out in AT1 as the taught aspect of the NoS. Process skills form the basis of the understanding required to carry out investigations and experiments. Consequently, this did have a high profile in the teaching and assessment of science (see for example section 7.8 and table 7.2 detailing the content of AT1 in the 1991 curriculum document (DES, 1991b) and the associated level statements). While process skills are part of the NoS, on their own they do not constitute a rounded and coherent view of the NoS.

A further issue related to intense changes in the SNC was the sudden and dramatic cut to content, along with a change from a conceptual approach of scientific 'big ideas' to a more traditional three sciences approach. This was accompanied by the removal of the NoS from the core content to the PoS in the 1991 SNC (DES 1991b). The reduction in content came from a realisation that delivering, let alone assessing the 409 separate statements that made up the science content was unreasonable. As noted in the 1991 draft curriculum, *'Under the existing Order there are 409 statements of attainment in science: a number we consider to be too large for manageable assessment.'* (DES, 1991a, p.iii). It was also noted that *'the first of the attainment targets, at present called 'Exploration of science', has not been well understood by parents or teachers.'* (DES, 1991a, p.iv). It was further noted within this proposed revision of the curriculum that the existing NoS content (AT17) would be divided between the new first attainment target (NAT1) and the history of scientific ideas within the 'introduction' to the curriculum. This split led to the NoS content being split between the AT statements, which was what teachers concentrated on teaching and the PoS, which was not a formal set of teaching statements that would be nationally tested within end of Key Stage tests or, to any great extent, within GCSE science examinations. Additionally, the use of the phrase *'pupils must be taught'* throughout the curriculum when the statements of attainment were listed, gave a specific instruction to teachers about what was important and must be delivered. Once more, the status of the NoS was being changed to its detriment due to its positioning within the curriculum document.

When the NoS did return to the core content, (e.g. in the 1995 curriculum (DfE, 1995) as 'Ideas and Evidence in Science' or in the 2004 version (DfES, 2004) as 'How Science Works') it did so under the guise of scientific enquiry. This subsuming of the NoS within the process skills of science reinforces the view that scientific enquiry was then acting

as a proxy for the NoS. The distinctiveness of the NoS was lost as the process skills, which was the main content of AT that 'must be taught', took priority (Nott and Wellington, 1999).

How the curriculum was organised and reorganised affected how the NoS was delivered (or not). The political need for accountability also affected how the curriculum was assessed. Judgements could be made on how successful schools (and teachers) were in delivering the core content of science through the end of key stage tests and the GCSE examination results.

#### **10.1.6 How does the incorporation (or lack) of the NoS affect how different scientific disciplines are viewed by science teachers?**

One fundamental aspect of the NoS that illustrates the key differences and similarities between the sciences is how scientific reasoning is used. Scientific reasoning was not made explicit within any of the versions of the SNC. Because of this, there is a lack of curriculum coherence at a macro (across science disciplines) and micro (within disciplines) level. This lack of coherence was compounded by the competing ideologies of curriculum reform at political, educational and organisational levels. While a key objective of the NC was one of commonality – that is children all studying the same things across the country – within the sciences this did not address the issue of coherence across the sciences. This lack of coherence is demonstrated by a lack of understanding of TSM.

From the interview data (Chapter 9) we see that there are varying levels of understanding and misunderstanding of TSM (section 9.8) as well as differing levels of understanding of key terminology used within science, such as theory, law etc. (section 9.9). The curriculum fails to anticipate these issues either through the NoS or by teaching a coherent view of TSM. As noted above, scientific investigation was promoted as a distinct attainment target that applied to all the science disciplines. It is also the case that there was no variance in approach to teaching AT1 within the curriculum documents, that is, all sciences were assumed to have common approaches to how they investigate scientific questions. In real life, physics tends to use a deductive approach (e.g. within theoretical physics), whereas biology is mainly inductive. An understanding of the NoS shows these differences, whereas over time, when AT1, which became Sc1 in the 1999 version of the curriculum (DfEE, 1999), took over as a proxy for the NoS, these differences were lost.

If a key outcome for science education is the development of scientific literacy for all, it could be argued that the teaching of the NoS should be a fundamental and core aspect



of such a curriculum given that the NoS is the basis of explaining what science is and how science operates. The NoS helps describe the distinctiveness of the different sciences, how they relate to one another and why they have similarities and differences. As demonstrated/argued in Chapter 7 (sections 7.4 and 7.5) it is fundamental to delivering scientific literacy.

It could be hypothesised that a lack of coherence could influence how teachers enact the curriculum as they seek their own version of coherence and an understanding of the epistemological and ontological basis for the different scientific disciplines. This, in turn, may affect the children who must then create their own coherent understanding of the sciences they are being taught. This hypothesis is something that could form the basis of further research.

Coherence can be affected by the standpoints of those creating, looking at and enacting any curriculum. The intent of any curriculum may be influenced by political ideology, the views of the writers and the views of those who enact the curriculum. As this case study shows, some of those 'intended' outcomes had the potential to generate problems for the curriculum. For example, the tensions between a traditional curriculum approach intended to be delivered in a traditional way, e.g. through direct instruction, versus a more progressive approach and style of teaching - a more child-centred/inquiry-based approach.

The curriculum detailed various process skills in practical and investigative science. This seems to have been used as a proxy for, rather than one (important) element of, the NoS (see Chapters 3 and 8). The critical thinking skills associated with investigative and inquiry-based science was neither explicit nor embedded within either the NoS or the skills of science. This is indicative of a failure to deliver a coherent approach to critical thinking skills and logical thinking processes or indeed argumentation. The effect of this is that a view of how scientists deal with data and/or observations collected through the application of process skills in scientific experiments and investigations is not cogently explained in the curriculum documents. Making sense of data, theory building/testing and developing scientific explanations for natural phenomena, as evidenced by the curriculum analysis presented in this case study, was not well developed within the curriculum. For example, there was no systematic attempt to deliver knowledge and understanding of inductive, deductive and abductive approaches to science and how such approaches help to distinguish different science disciplines or, given their applicability in many disciplines, how they tie the different science disciplines together.

## **10.2 Limitations of the research**

All research has strengths and weaknesses and this research is no different. The general strengths and weaknesses are outlined in Chapter 4 section 4.20. In addition, there were limitations that were explored in section 4.24 concerning the selected approach and decisions made by this researcher that affect the quality of the research and potential outcomes.

This research was not without its problems. There are limitations surrounding: the documentation (such as potential gaps in the documentation analysed); the interviews with serving teachers (the overall number and some unexplored aspects of their experiences of being taught under the NC); the lack of interviews with any members of the original working groups and people involved in the construction and revision of the curriculum, as well as issues over consent to use interview data. All these factors impose limitations on the analysis provided (for a fuller discussion see section 4.24).

### **10.2.1 Documentation used in the document analysis phase**

Much of the documentation analysed was built up during my own career in science teaching and initial teacher education (ITE). A lot of official documentation was available online, but draft copies, working documents etc. were either not available (e.g. from a search of the national archives) or no longer existed. It would be wrong to claim that all the relevant documentation relating to the development and subsequent revisions of the SNC was identified and subjected to a full content analysis. However, it was possible to locate and analyse key acts of parliament, key reports and the draft and enacted SNC documents (see appendix A). The analysis and interpretation of those documents formed a large part of this thesis. Drafts and revisions of the published reports used within this case study could not be accessed. Where authors were identified it would, technically, have been possible to try and interview living contributors (see section 10.7.3 below) with a view to discovering the underlying intent of the author with respect to the report and any recommendations made. A lack of time and available resources made this impractical. These limitations mean that the outcome of the documentary analysis and the interpretation of the political, organisational and educational influences was going to be limited by some gaps. Nevertheless, the documents I could access and my own engagement and contributions to the science curriculum in England e.g. my work in creating national Schemes of Work for Key Stage 3, as well as being a member of groups commenting on drafts of the proposed revisions of the science curriculum, as a member of the ASE, enhanced the credibility of the findings and conclusions.

### 10.3 Contributions to knowledge

This section discusses the four key contributions to knowledge that arise from this case study:

1. **Undermining Scientific Literacy:**

A lack of a properly formed and informed view of the Nature of Science in the science curriculum has the potential to undermine the development of high levels of scientific literacy.

2. **Process skills acting as a proxy for the nature of science:**

The process skills of science, that is how to conduct experiments and investigations, have the potential to be seen as a proxy for the NoS if a coherent position on the NoS is not presented as necessary to underpin science teaching.

3. **The failure of a curriculum by consensus:**

The creation of a curriculum by consensus with very prescriptive detail was ineffective and led to several revisions which further complicated its implementation nationally.

4. **Vernacular vs specific terminology and the need to be specific about ‘the scientific method’:**

There is a problem with the lack of agreement and consistent definitions of key terms and the concept of ‘the scientific method’, as revealed in the interview evidence, which undermines the teaching and understanding of the nature of science.

#### 10.3.1 Undermining scientific literacy

A key finding and contribution to knowledge arising from this case study is that the lack of a consistent view of the NoS has the potential to undermine the achievement of Bybee’s (1997) description of multi-dimensional scientific literacy. If teachers cannot articulate the NoS (as indicated in the research literature and the interviews of the science teachers for this study) and they have confused ideas about TSM, as well as inconsistent or incorrect definitions of key scientific terminology (as also shown in the literature and interviews), then we cannot with confidence claim that the curriculum will deliver the highest levels of scientific literacy. To achieve high levels of scientific literacy (e.g., Bybee’s (1997) model which has conceptual and multi-dimensional literacy at the highest level), teachers need an understanding of the NoS and this must include aspects of scientific reasoning (see Chapter 7 sections 7.4; 7.5; 7.6). As Bybee (1997) shows, children need to understand the essential conceptual structures of science and technology from a broader perspective that includes the history and philosophy of science. They also require an understanding of the relationship of the disciplines to the whole of science and technology and to society. The removal of the NoS as a distinct, formally taught and tested aspect of the SNC and its reintroduction as ‘How Science Works’ or even ‘Working Scientifically’ had the potential to undermine the development of scientific literacy, as the curriculum no longer provided a coherent concept of the NoS.

### **10.3.2 Process skills acting as a proxy for the nature of science**

The changes in the status and content of the NoS from its first well thought out form as a discrete attainment target led to a position where process skills were used as a proxy for the NoS. This was apparent as the NoS partly moved into the PoS and the first AT became one that was mostly about the process skills of science (see Chapter 7, section 7.3). The Interviews with serving teachers (discussed in Chapter 9) also exposed misunderstandings and misconceptions about TSM and key terminology (for example, some were confusing TSM with how to ‘do’ experiments and investigations. Scientific reasoning skills were also not always well understood and key terminology that is central to understanding the NoS was also not always well articulated). The first SNC (DES, 1988b) correctly identified the NoS as an underlying basis on which science content should be delivered and treated the inquiry aspect of science as a contributing aspect to the NoS. The demotion of the NoS to the programme of study in the 1991 version of the SNC (DES, 1991b), albeit with advice that it should still underpin the science content, led to a situation where the NoS was unlikely to be well integrated, or perhaps not even integrated at all into teaching. The reversion to the *status quo*, that is the traditional three sciences, had the effect of almost eliminating the NoS from the curriculum. Additionally, the move to create an attainment target for investigation had the effect of this becoming a proxy for the NoS in teaching. Attempts to redress the loss of the NoS from the science content, through the introduction of concepts such as ‘How Science Works’ or ‘Ideas and Evidence in Science’, reinforced the idea of scientific investigation as a proxy for the NoS. The prominent content was on the process skills of science rather than the attributes of science and a thorough understanding of scientific reasoning, alongside the history and philosophy of science.

### **10.3.3 The failure of the curriculum by consensus**

In 1988, the idea of a curriculum by consensus, which would be adopted nationally, and which has to serve (currently) over 8.5 million children and many thousands of teachers was ambitious. As it turned out, it was unsuccessful when it came to deliver a coherent understanding of the NoS. The initial consultation for then ‘new’ SNC represented a major shift from what had previously existed (that is, no formal, nationally agreed curriculum). The original, and to a large extent the following revisions of the curriculum, were too prescriptive and couched in a language that was so different from the curriculum language in use that teachers, in particular, did not understand easily how the curriculum was structured and how it could be enacted (see Chapter 5 section 5.4.2). This finding has implications for how a science curriculum could, and should, be constructed (see recommendations below).

The evidence from this case study shows that the various influences (political, educational and organisational) on the construction of a new national curriculum led, in the case of science, to a curriculum of consensus that, when enacted in 1989, was not fit for purpose. That curriculum underwent a period of rapid change and ‘reverted’ to what had been a *status quo* in how the various disciplines in the sciences were viewed, that is as biology, chemistry and physics. The change went from a curriculum of consensus to one that was the result of the work of a small cohort of science HMIs who oversaw the return to the ‘norm’ of teaching about the ‘three sciences’ (see section 7.8). This change facilitates the teaching of ‘science literacy’, that is, knowing facts **in** science, but it does not help in delivering ‘scientific literacy’, knowing not just facts **in** science, but also the epistemological and ontological basis for science as an academic discipline.

Without an underlying epistemological basis for science, attempting to teach scientific reasoning is difficult. If children do not understand how science arrives at explanations (theories) in different ways e.g. through deductive, inductive or abductive logic, this undermines a fundamental aspect of higher levels of scientific literacy (section 3.5). The curriculum encouraged the teaching of science literacy, the acquisition of scientific knowledge (facts). Tests and examinations (even today) concentrate more on knowledge acquisition than conceptual understanding and this is/was encouraged by politicians in their framing of the outcomes of education, e.g. the focus on improved test scores and examination grades.

#### **10.3.4 Vernacular vs specific terminology and the need to be specific about ‘the scientific method’**

There is a problem with the use of scientific language and potential confusions between specific scientific definitions of terms and their use as everyday terms with vernacular meanings. The teacher interviews showed some confusion over the specific meaning of terms (see Chapter 9, section 9) and in one case, where a participant withdrew consent for data to be used, the confusion over the meanings of terms led to an undermining of the confidence of the teacher (see Chapter 4, section 4.23.2). Without commonly understood and used definitions of key terminology, the status of scientific knowledge is undermined. If meanings have fluidity the specificity that science is built upon is undermined. One simple solution with respect to the language of science would be the use of the prefix ‘scientific’ to each of the key terms (see recommendations, section 10.5).

There is also confusion surrounding what is meant by ‘the scientific method’ (TSM). There is no ‘one’ way to do science. That is, there is no single scientific method. In

practice, there are methods of doing science that vary between scientific disciplines and the nature of the experiments that scientists wish to carry out. Evidence from the interview data suggests that teachers may interpret this to mean simply how to write up a laboratory description of 'how' a scientific investigation or experiment is carried out.

The methods utilised by different disciplines are often dependent on the data or evidence being gathered. The SNC, with its emphasis on experimental and investigative skills, has inadvertently promoted scientific inquiry as a proxy for the NoS. While the methods of science do form part of the NoS it is not how the NoS should be defined. While there remain disagreements over an exact definition of the NoS, the key characteristics as set out in section 1.1) are common characteristics that are widely used (Lederman *et al.*, 2002; Lederman, 2007).

The potential danger in using scientific inquiry as a proxy for the NoS is that it could allow for non-scientific ideas to be defined as 'scientific'. It has the potential to leave the impression that to be 'scientific' something must simply follow 'the scientific method'. This would be an interesting area of research. Simply because scientific methods are used, does not make something 'scientific'. For example, an astrologer may use scientific methods to measure the position and movement of planets and the apparent movement of constellations. The same methods will be used by astronomers. The resultant outcomes or predictions of the two will be very different. An astronomer may predict the future path of a planetary body, location of a constellation or star, or an asteroid, whereas an astrologer predicts the characteristics of people and possible future events. Understanding the NoS reveals why the astronomer is scientific (using evidence and scientific reasoning) and the astrologer is unscientific coming to conclusions, but not using logic or scientific reasoning.

#### **10.4 Recommendations from this case study**

Having concluded this case study, what has been learned now needs to be placed in a wider context, both nationally and internationally. Science education is a core subject in the curriculum of many countries. It is often seen as an essential subject for improving the economic fortunes of a country. A supply of scientists and engineers is seen as a crucial part of the workforce provision in economically successful countries. While a case study may not lead to generalisations, it can illustrate problems and practices that could have wider implications that help inform curriculum developers, policy makers and teachers.

To understand the political ideologies, motivations and driving forces for curriculum change, it is necessary to ensure that what is put in place does not, first and foremost,

simply meet the needs of politicians who may see education and the curriculum as a means to achieving political goals, such as winning votes from the electorate. From an organisational position, curriculum developers must carefully consider the time constraints of the whole school curriculum, access to specialist equipment and locations (laboratories) to ensure a coherent and accessible curriculum can be delivered.

The main recommendations arising from this case study relate to acknowledging the role of political, organisational and educational influences in the creation of a curriculum and understand the role the NoS has in developing high-level scientific literacy. The key recommendations are divided into three groups:

### **Educational**

Curriculum developers should be clear on the intention of the curriculum with respect to the desired outcome. For example, is the curriculum intended to deliver scientific literacy or improve science literacy? The role of the NoS as an underpinning concept in the development of scientific literacy must also be recognised by curriculum writers and given parity of esteem with other aspects of the curriculum such as process skills as well as concept development and understanding. Subject knowledge enhancement programmes for pre-service/trainee science teachers should include a greater awareness and understanding of the NoS, TSM and scientific reasoning. There should be explicit teaching of key terminology associated with the NoS, such as theory, law, hypothesis, etc. Key terminology associated with the NoS should be prefixed by the term 'scientific' when using the terms within science teaching and learning.

### **Organisational**

Science curriculum developers need to acknowledge the different characteristics that the different science disciplines have and avoid imposing a single structural framework on all subject disciplines.

### **Political**

Assessment must not be a 'system of convenience' for meeting political accountability. The role of 'league tables' as the main or dominant form of accountability measure should be reviewed to remove the 'political' aspect of curriculum delivery.

#### **10.4.1 Educational recommendations**

From an educational standpoint, the writer of a science curriculum should make clear if the intention is to promote the delivery of scientific literacy for all or to deliver science literacy (see section 3.4) as a means of increasing uptake in Science, Technology, Engineering and Mathematics (STEM) subjects at higher levels e.g. at A level, or beyond to degree level.

It is necessary to acknowledge the role the NoS has in developing scientific literacy. Any new curriculum being developed for science should have the NoS as a solid base on which other aspects of science, such as concept development and skills acquisition is built. Understanding the epistemological basis of science as a subject is critical to developing multidimensional scientific literacy. Whether a curriculum is being developed top down (that is a common core science curriculum at a national level) or bottom up, a science curriculum being developed by schools or teachers for local use, a well thought out and informed vision of the NoS is critical.

This case study, in line with other research (Lederman, 1992; 2004; Buffler *et al.*, 2008; Teresa Guerra-Ramos, 2012; Aydeniz and Bilican, 2014; Mihadiz and Dogan, 2014), shows that teachers do not necessarily have a well-informed view and understanding of the NoS. This leads to a recommendation that could be widely implemented. Subject knowledge enhancement (SKE), which is commonly provided for many pre-service/trainee science teachers in England before commencing their ITT programmes, could include discussion of and understanding about the NoS and TSM. SKE could cover what the NoS is, how it informs scientific reasoning and process skills, and how the history and philosophy of science can inform children's understanding of key scientific concepts. It would also broaden understanding of the ethical and moral aspects of science and how creativity contributes to scientific knowledge and understanding. This should form part of a science teacher's initial training and could be offered as Continuing Professional Development (CPD) for serving teachers. Achieving this against the background of political influences will not be simple. The best way to achieve it would be for the expert subject groups (e.g. the ASE, Royal Society of Biology etc.) to join and make evidenced calls for changes to initial teacher education in the sciences. This would involve undertaking a review of the ITT curriculum of major providers, which in England includes University led, Teach First and school-based provision, to ascertain what is currently delivered. The existing situation politically is that subject knowledge (in the sense of knowledge of biology, chemistry and physics) is important. The NoS, TSM and scientific reasoning is not a political priority. There is a case to be made that the NoS is equal to the development of subject knowledge, though this case needs to be stated and presented to the politicians who, in England, substantially determine the content of and fund ITT.

Recognising the importance of the NoS should be accompanied with explicit teaching directed at pre-service/trainee science teachers about the terminology associated with science (such as theory, law, hypothesis etc.) and understanding the fluidity of meaning that words have when used in a specific sense and a general sense. This should also be



accompanied by an understanding of the relationship and differences between theories, laws, principles and hypotheses. If teachers and, ultimately, children see the relationship as linear and hierarchical it will promulgate a misconception that within science the highest and most secure level of understanding and knowledge only applies when something becomes a 'law'.

The use of the prefix 'scientific' by teachers, textbook writers and curriculum developers when using key terminology related to the NoS, as in 'scientific theory'; 'scientific hypothesis'; 'scientific law' etc. would enable the specific scientific meaning to be clear. This would ensure that children (and their teachers) understand that the term being used has a specific scientific meaning that should not be confused with a general or vernacular meaning.

#### **10.4.2 Organisational recommendations**

This case study illustrates some of the issues that surround the development of a subject curriculum within the framework of a wider national curriculum. Developing a curriculum by consensus led, in England and Wales, to an unwieldy, burdensome subject curriculum that could not be delivered by teachers. This was recognised by the draft 1991 review of the curriculum (DES, 1991a) and the subsequent Dearing review (Dearing, 1994). For curriculum developers, there are lessons that can be learned from how events - political, educational and organisational - can complicate major curriculum projects. For example, if a general curriculum is to be applied nationally, it must recognise the different characteristics that different subjects have and, in the case of science the different characteristics that the different science disciplines have.

Imposing a single structural framework on all subject disciplines works against creativity, restricts how different subjects could present their content and how different teachers deliver the content. The problem in the case of England is that currently (as historically) political control, driven by a political ideology, has an overriding effect on what curriculum can be delivered.

#### **10.4.3 Political recommendations**

The initial assessment framework for the English and Welsh curriculum was predicated on 10 levels that were 'levels of convenience' in that they represented approximately one level for each year that a child was subject to the curriculum. Children's progress is neither linear nor incremental (Bransford *et al.*, 2000). A lesson for curriculum developers here is not to impose upon teachers and schools a system of assessment for convenience. The difficulty is how we prevent such systems of convenience from happening. The use of 'convenient systems' to inform league tables is a prominent

political driving force. The removal of league tables would reduce the need for such 'convenient systems' and allow for more informed systems of assessment to be put in place.

There was also a political motive in imposing a national curriculum. Until 1988, schools and teachers were not necessarily held to account nationally. There was local accountability through the local education authorities, but politicians were interested in being more involved in educational outcomes and holding schools and teachers to account. This set up tensions and had the effect of changing how subjects were taught, as teachers taught more to the test. The test result being the main measure against which schools and teachers were held to account.

Ideally a curriculum will not have as a driving force a political imperative. Such a situation is not unknown. In Finland for example, there has been a deregulation of state control over education. After a period of increased state control from the late 19<sup>th</sup> century to the 1980s, there has been a steady reduction in state control over Finnish education, including the curriculum and its content. Teachers have more freedom to decide on their preferred pedagogical approach and to decide the content of the curriculum such that it meets the needs of the children (Kosunen and Hansen, 2018). The situation, which exists today in the UK, particularly England, is that political forces are in place. This requires curriculum developers to develop much stronger arguments for rejecting the political structures in favour of more evidenced curriculum structures that serve the development of understanding, leading to scientific literacy. What underpins such understanding is the NoS as articulated in Bybee's (1997) description of 'multidimensional scientific literacy' (see figure 3.1).

### **10.5 The science curriculum since 2010**

This case study was time bound between 1988 and 2010. Since 2010, one major revision of the science curriculum was issued in 2014. What follows is a brief summary of the political, organisational and educational situation with respect to recent curriculum reforms and a summary of the status of the nature of science in the newer, post 2010 curriculum.

#### **10.5.1 The political scene from 2010 to 2018**

In 2010, as noted earlier, a new government was elected, but there was no overall single party majority. This meant that a coalition government was formed between the Conservative Party and the Liberal Democrats. David Cameron, the new Conservative Prime Minister, put in post Michael Gove, as Secretary of State for Education. This was an appointment that Gove had indicated previously he would like in any future

Conservative government (Gove, 2009). Gove immediately set about redefining the content of the school curriculum and the structure of school accountability. His structural changes included how schools were to be governed. One of his first acts was the implementation of mass academisation of schools and the creation of 'Free Schools'. Essentially, Gove was taking initiatives from elsewhere, for example the charter schools in the United States, and applying these to the English state school system. Under Gove, there was a further centralisation of control of schools. For example, the local authorities were systematically excluded from the oversight of schools and holding schools to account. Originally, the academies programme was a New Labour initiative of the Blair government. Michael Gove saw the programme as a useful way of removing any remaining local authority control over schools. Gove's new system brought in a different form of accountability, where the DfE directly funded and oversaw academies and groups of academies were overseen by government approved 'Trusts'. This was presented as a form of 'decentralisation' giving more control to Headteachers, but it was, in reality, tighter control from the centre.

There were two important things associated with the academies programme. One was that the schools were deemed to be independent schools. Independent schools could decide their own curriculum and were not tied to delivering the NC. It is in this respect that they were deemed to be independent. Although curriculum independence was promoted as a good thing by Gove, few, if any, academies did not deliver the national curriculum. GCSE specifications are predicated on the NC therefore it was a hollow promise that schools could be truly independent and deliver a curriculum that did not contain NC subjects. Centralised control over schools and academies was further entrenched when Gove promoted the idea of an English Baccalaureate (EBacc) meaning that schools were (and still are) accountable for the delivery of a core of NC subjects called 'progress eight'. Progress eight includes English; mathematics; three other EBacc subjects (sciences, computer science, geography, history and languages); and three further subjects, which can be from the range of EBacc subjects, or can be any other approved, high-value arts, academic, or vocational qualification.

The coalition government lasted for five years. During this time, it has been argued that the Liberal Democrats held back some of the more controversial ideas that Gove may have had with respect to schools and the curriculum (West, 2015). Others argue that the Liberal Democrats may have positively affected the structural and organisational aspects of schools, for example, with their insistence for universal infant free school meals (UIFSM), but that ultimately their coalition reign was very damaging to their own party (e.g. Cutts and Russell, 2015).

With respect to the curriculum, Michael Gove was keen to review and change the content of some subjects, most notably history (Burn, 2015). There is no evidence that he personally directed any changes relating to the science curriculum content. What is known, is that Gove wanted curriculum reform across all subjects to increase rigour as well as the intellectual demands on all examination subjects. In addition, he changed the nature of A level examinations by abolishing the link between AS and A level and making examinations end of course synoptic ones rather than modular. At the time of writing cohorts of children in schools are taking these examinations even though Michael Gove was replaced in 2014. The 'legacy' of political influence far outlives the politician, who often moves on to other posts.

In 2015, a General Election was called as a result of the newly implemented fixed term parliament act that required an election after five years in office (though elections could be called by majority vote before the five-year period expired). The Prime Minister, David Cameron, was returned to office. A referendum on EU membership (a Conservative party manifesto promise) resulted in a vote to leave. David Cameron resigned and a newly elected leader of the Conservative Party, Theresa May, became Prime Minister in 2016.

May called a snap election in 2017 that resulted in a much-reduced majority for the Conservative Party. During this period, due to the vote leave decision, much of politics was dominated by discussion about negotiations with the EU over a withdrawal agreement. This led to education policy and matters relating to schools being less exposed in the media, with fewer policy actions and government initiatives, though problems relating to funding cuts remained in the public eye (Weale and Adams, 2019).

Selective education was an issue highlighted in the 2017 election, though it is still a minor provision within state education. It is, however, dominant in private schools and the remaining 163 state Grammar Schools in England. The current government is disposed to enable some schools to expand their selective provision bypassing legislation that rules out the establishment of new Grammar schools through the notion of expansion. In 2019, the Conservative Government pledged £50 million for Grammar School expansion (Busby, 2019). There is also evidence that academies are now introducing a 'grammar stream' within some schools with a comprehensive intake (Richardson, 2017). Such streams offer a modified curriculum which includes separate sciences, rather than combined or integrated sciences, and which concentrate on the academic rather than vocational subjects. One problem with such developments is the privileging of separate sciences as an elite set of subjects for the higher attaining pupils only.

### 10.5.2 The science curriculum 2010 – 2018

In 2011, Michael Gove initiated extensive reforms of all the national curriculum subjects for the national curriculum for England. The proposed curriculum reforms were based on a White Paper called 'The Importance of Teaching' (DfE 2010). The White Paper confirmed the government intention to reform the whole national curriculum with a view to reducing the core content and being less prescriptive.

In the January of 2011, an expert panel was formed to lead the review of the whole curriculum, led by Tim Oates, then Director of Assessment Research and Development for Cambridge Assessment. After a relatively short review period, the final report was published in December 2011 (James *et al.*, 2011). While Michael Gove desired a fast implementation of a reformed curriculum (Adams, 2014), it became clear from an organisational and educational perspective that a fast, but major change to the curriculum and the associated assessments would not be possible. For example, new, more demanding content would require new textbooks which cannot be produced quickly. Additionally, examinations would need alignment to the new specification content. It was quickly noted that the timetable for the implementation of the curriculum needed to be altered. It was not until June 2012 that the government published the draft programmes of study for the core subjects of English, maths and science at KS1 and KS2, for discussion. Reactions to the June 2012 consultation were not overly positive. Professor Andrew Pollard, a member of the expert panel, stated that in his view the proposals were '*fatally flawed*' (Paton, 2012). The National Association of Headteachers (NAHT), however, praised the slimmed down science curriculum for Key Stages 1 & 2 (Roberts, 2014). There were further consultations on the content of the new, revised curriculum documents in February and July 2013. The first implementation and teaching of the new, revised core subjects (English, maths, science, P.E.) was changed from September 2013 to September 2014.

The change in the curriculum had consequences for how the curriculum was to be assessed. In June 2011 it was recommended that NC levels should be abolished to allow schools and teachers more freedom to internally assess and track pupil progress. After more than 20 years using 'levels' this new freedom created more problems for schools as teachers were so used to 'levelling'. When levels were finally removed, it was noted that schools either tried to recreate or adapt the existing levels to the new curriculum or created 'new' models of assessment that were, in themselves, no more than levels by another name (NASUWT, 2017). A lesson here is the creation of dependency on a curriculum and a curriculum structure that could have the effect of de-professionalising teachers as they simply follow the stated curriculum and apply a given assessment

regime. The curriculum could be seen as being ‘assessment led’ rather than content or concept led. The previous curriculum with its levelled assessments had generated complex systems of levels and sub-levels to try and describe children’s progress (Harlen, 2014). The move to abolish levels was an attempt to prevent further complex ‘levelled’ systems of internal assessment.

The changes to the science curriculum included changes to the basic content with, for example, new content on aspects of evolution and the solar system. There was also a greater emphasis on teaching about climate change. At Key Stages 3 & 4 it was intended that there should be a much clearer division of the science content to the three core science subject disciplines of biology, chemistry and physics, echoing the change in 1991 which reverted to ‘mostly biology’ etc. Within this change, there was also the intention to deliver more factual content in the form of ‘scientific knowledge’. One teaching union, the NASUWT, described fundamental issues in how teachers perceived curriculum content and what they focused on as being the imperative that teachers perceived to be important. This echoes the position that developed and is described within this case study:

National Curriculum teaching was always intended to be guided by programmes of study. However, in practice, attainment targets and level descriptors came to dominate curriculum design in many schools... this practice was driven in large part by the way in which schools perceived the imperatives of the school accountability regime. (NASUWT, 2017, p.7)

The NoS was maintained, but the problems of treating the processes of science as a separate rather than integral part of the NoS remained. In the new SNC one key statement covers the programme of study content for aspects of the NoS:

develop understanding of the nature, processes and methods of science through different types of science enquiries that help them to answer scientific questions about the world around them (DfE, 2015)

One positive change is the addition of the phrase ‘methods of science’ and the specification of ‘different types of science enquiries’ to help answer scientific questions. If this is interpreted by teachers as understanding the differences between the scientific disciplines through the different methods of enquiry they use, and that science ‘enquiries’ are described as ways of scientific reasoning, this would be a major step toward a more coherent view of the NoS. Such a step would more closely align with the characteristics set out in Chapter 1 of this thesis, namely: distinguishing between observation and inference, laws and theories; creativity and imagination; the subjective nature of scientific

knowledge; science as a human enterprise and that scientific knowledge is never absolute of certain.

### **10.6 Overall conclusion**

How we define and implement a given curriculum is a complex process. Lessons from this case study show that neither an imposed, nor a consensus curriculum, will necessarily be successful. That said, it is essential for those involved in the writing of a curriculum to be clear on its purpose. Is it about skills and training? Or is it about gaining an understanding of the nature of the subject and how knowledge is created? To achieve both requires careful planning. A curriculum that professed to be all things and to serve all abilities and potential outcomes had not been achieved, as this case study indicates, through the construction of a NC. The political, organisational and educational tensions interfered with coherence on a range of levels, from the macro-level across the different science disciplines and at a micro-level within the subject discipline and within the school curriculum.

A curriculum must also avoid being constructed on an assumption that coherence can be achieved or that content will be universally understood if those who are charged to deliver it come from different disciplines. The SNC was predicated on five separate scientific disciplines, with, often, an expectation that in lower secondary teachers would deliver all five disciplines, regardless of their own specialism, to children aged 11-14, even up to the age of sixteen.

A SNC is currently in operation across England. What this case study shows is that much work is needed to bring the NoS to the fore if we are to achieve what is, after all, one of the stated goals of this and many other curriculums for science, that is, delivering a high level of scientific literacy for all.

## Bibliography

- Abd-El-Khalick, F. (2013) Teaching With and About Nature of Science, and Science Teacher Knowledge Domains. *Science & Education*, 22 (9), 2087-2107.
- Abd-El-Khalick, F. & Lederman, N.G. (2000) Improving science teachers' conceptions of nature of science: a critical review of the literature. *International Journal of Science Education*, 22 (7), 665 - 701.
- Abd-El-Khalick, F., Bell Randy, L. & Lederman Norman, G. (1998) The nature of science and instructional practice: Making the unnatural natural. *Science Education*, 82 (4), 417-436.
- Abrams, F. (1994) Changes that led to testing at key stages 2 and 3 the history of the much criticised national curriculum *The Independent*, p. 4.
- Acland, D.A.H. (1909) Attendance, Compulsory or Otherwise at Continuation Schools. *Board of Education. London: HMSO.*
- Adams, R. (2014) Michael Gove: a controversial but influential education secretary *The Guardian*.
- Adams, R. (2017) NUT weighing up legal action against academies over 'grammar streams'; Some schools are unlawfully trying to sneak selection in through the backdoor, says UK's largest teaching union *The Guardian*.
- Aguirre, J.M., Haggerty, S.M. & Linder, C.J. (1990) Student-teachers' conceptions of science, teaching and learning: a case study in preservice science education. *International Journal of Science Education*, 12 (4), 381-390.
- Allchin, D. (2014) From Science Studies to Scientific Literacy: A View from the Classroom. *Science & Education*, 23 (9), 1911-1932.
- Alters, B.J. (1997a) Nature of science: A diversity or uniformity of ideas? *Journal of Research in Science Teaching*, 34 (10), 1105-1108.
- Alters, B.J. (1997b) Whose nature of science? *Journal of Research in Science Teaching*, 34 (1), 39-55.
- Alvesson, M. & Skoldberg, K. (2009) *Reflexive Methodology: New Vistas For Qualitative Research: New Vistas in Qualitative Research*. London: Sage Publications Ltd.
- Anonymous (1990) Comment: No minister. *New Scientist. Issue No. 1729*
- Anonymous (1998) Why Do We Need Science, Anyway? *Every Child a Scientist: Achieving Scientific Literacy for All*. Washington, DC: The National Academies Press.
- Anonymous (2002) Estelle Morris resigns *Daily Telegraph*.
- Anonymous (2006) *Creationism to be in GCSE papers* [online]. BBC. Available from: <http://news.bbc.co.uk/1/hi/education/4793198.stm> [Accessed August 12th 2016].



- Anonymous (2016a) *Archimedes' principle* [online]. Encyclopedia Britannica. Available from: <https://www.britannica.com/science/Archimedes-principle> [Accessed August 28th 2016].
- Anonymous (2016b) *Are science and Christianity at war?* [online]. <http://biologos.org/common-questions/christianity-and-science/science-and-religion> [Accessed 14th August 2016].
- Anonymous (2018a) *Lord's rallying education plea* [online]. Newsquest Ltd. Available from: [http://www.theargus.co.uk/news/16042870.Lord\\_\\_\\_s\\_rallying\\_education\\_plea/](http://www.theargus.co.uk/news/16042870.Lord___s_rallying_education_plea/) [Accessed 24th February 2018].
- Anonymous (2018b) *Nuffield Combined Science* [online]. National Stem Centre. Available from: <https://www.stem.org.uk/resources/collection/3051/nuffield-combined-science> [Accessed 10th February 2018].
- Armstrong, H.E. (1902) The Heuristic Method of Teaching. *School Science and Mathematics*, 1 (8), 395-401.
- Armstrong, H.E. (1903) *The teaching of scientific method and other papers on education*. London: Macmillan and Co.
- Armstrong, H.E. (1973) *H.E.Armstrong and Science Education: Selections*. London: John Murray Publishers Ltd.
- Aslan, O. & Tasar, M.F. (2013) How do Science Teachers View and Teach the Nature of Science? A Classroom Investigation. *Egitim Ve Bilim-Education and Science*, 38 (167), 65-80.
- Aydeniz, M. & Bilican, K. (2014) What do Scientists know about the nature of science? A case study of novice scientists' views of NOS. *International Journal of Science and Mathematics Education*, 12 (5), 1083-1115.
- Backhus, D.A. & Thompson, K.W. (2006) Addressing the Nature of Science in Preservice Science Teacher Preparation Programs: Science Educator Perceptions. *Journal of Science Teacher Education*, 17 (1), 65-81.
- Baker, K. (1993) *The turbulent years: my life in politics*. London: Faber.
- Ball, S.J. (1990) *Politics and policy making in education: explorations in policy sociology*. London: Routledge.
- Ball, S.J. (1995) Culture, crisis, and morality. *Discourse and Reproduction: essays in honour of Basil Bernstein*. New York, Hampton Press.
- Bauer, H.H. (1994) *Scientific Literacy and the Myth of the Scientific Method*. Chicago: University of Illinois Press.
- Bayir, E., Cakici, Y. & Ertas, O. (2014) Exploring Natural and Social Scientists' Views of Nature of Science. *International Journal of Science Education*, 36 (8), 1286-1312.
- Bektas, O., Ekiz, B., Tuysuz, M., Kutucu, E.S., Tarkin, A. & Uzuntiryaki-Kondakci, E. (2013) Pre-service chemistry teachers' pedagogical content knowledge of the nature of science in

the particle nature of matter. *Chemistry Education Research and Practice*, 14 (2), 201-213.

Belgutay, J. (2018) First T levels subjects announced *TES*, 11th October 2017.

Bell, J.F. (2001) Patterns of Subject Uptake and Examination Entry 1984–1997. *Educational Studies*, 27 (2), 201-219.

Bell, R.L., Lederman, N.G. & Abd-El-Khalick, F. (2000) Developing and acting upon one's conception of the nature of science: A follow-up study. *Journal of Research in Science Teaching*, 37 (6), 563-581.

Benjamin, A.C. (1956) Is There a Scientific Method? *The Journal of Higher Education*, 27 (5), 233-238.

Bennett, J., Lubben, F. & Hampden-Thompson, G. (2013) Schools That Make a Difference to Post-Compulsory Uptake of Physical Science Subjects: Some comparative case studies in England. *International Journal of Science Education*, 35 (4), 663-689.

BERA (2011) *Ethical Guidelines for Educational Research* [online]. British Educational Research Association. Available from: <https://www.bera.ac.uk/researchers-resources/publications/ethical-guidelines-for-educational-research-2011> [Accessed October 25th 2017].

Berger, P.L. & Luckmann, T. (1966) *The Social Construction of Reality: A Treatise in the Sociology of Knowledge* (Penguin Social Sciences). New York: First Anchor Books.

Berghoff, H. (1990) Public schools and the decline of the British economy 1870–1914. *Past & present*, 129 (1), 148-167.

Bilican, K., Tekkaya, C. & Cakiroglu, J. (2012) Pre-service science teachers' instructional planning for teaching nature of science: a multiple case study. *Procedia - Social and Behavioral Sciences*, 31 (0), 468-472.

Bird, A. (2010) The epistemology of science—a bird's-eye view. *Synthese*, 175 (1), 5-16.

Black, P. (1995a) 1987 to 1995 — The Struggle to Formulate a National Curriculum for Science in England and Wales. *Studies in Science Education*, 26 (1), 159-188.

Black, P. (1995b) Curriculum and assessment in science education: the policy interface. *International Journal of Science Education*, 17 (4), 453-469.

Blair, T. (2011) *A Journey*. London: Arrow Books.

Blanco, R. & Niaz, M. (1997) Epistemological beliefs of students and teachers about the nature of science: From 'Baconian inductive ascent' to the 'irrelevance' of scientific laws. *Instructional Science*, 25 (3), 203-231.

Bloom, J.W. (1989) Preservice elementary teachers' conceptions of science: science, theories and evolution. *International Journal of Science Education*, 11 (4), 401 - 415.

Bolton, P. (2012) *Historical statistics*. London: House of Commons.

- Bowen, G. A. (2009) Document Analysis as a Qualitative Research Method. *Qualitative Research Journal*, 9 (2), 27-40.
- Bowler, P.J. & Pickstone, J.V. (2009) *The Cambridge History of Science: Volume 6: The Modern Biological and Earth Sciences*. Cambridge: Cambridge University Press.
- Boyle, B. & Bragg, J. (2006) A curriculum without foundation. *British Educational Research Journal*, 32 (4), 569-582.
- Bradie, M. & Harms, W. (2001) *Evolutionary Epistemology* [online].  
<https://plato.stanford.edu/entries/epistemology-evolutionary/> [Accessed November 15th 2017].
- Bransford, J.D.E., Brown, A.L.E. & Cocking, R.R.E. (2000) *How People Learn: Brain, Mind, Experience, and School: Expanded Edition*. National Academies Press.
- Braun, V. & Clarke, V. (2006) Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3 (2), 77-101.
- Braund, M. & Driver, M. (2005) Pupils' perceptions of practical science in primary and secondary school: implications for improving progression and continuity of learning. *Educational Research*, 47 (1), 77-91.
- Brickhouse, N.W. (1990) Teachers' Beliefs About the Nature of Science and Their Relationship to Classroom Practice. *Journal of Teacher Education*, 41 (3), 53-62.
- Brock, W. (1977) Formalising Science in the School Curriculum. *New Scientist*. 75 (1068) pp. 604-607.
- Buffler, A., Lubben, F. & Ibrahim, B. (2008) The Relationship between Students' Views of the Nature of Science and their Views of the Nature of Scientific Measurement. *International Journal of Science Education*, 31 (9), 1137- 1156.
- Burbules, N.C. & Linn, M.C. (1991) Science education and philosophy of science: congruence or contradiction? *International Journal of Science Education*, 13 (3), 227-241.
- Burn, K. (2015) The Gove legacy in the curriculum: The case of history. In Finn, M. (eds) *The Gove Legacy: Education in Britain after the Coalition*. London: Palgrave Pivot pp. 47-62.
- Busby, E. (2019) *Government gives 16 grammar schools in England a share of £50m funding pot to expand* [online]. Independent Newspapers. Available from:  
<https://www.independent.co.uk/news/education/education-news/grammar-schools-england-funding-government-academic-selection-department-for-education-a8664691.html> [Accessed 20th February 2019].
- Bybee, R.W. (1997) *Achieving Scientific Literacy: From Purposes to Practice*. London: Heinemann
- Callaghan, J. (1976) speech at Ruskin College. *Oxford*, 18, 1-72.
- Carroll, M. & Gill, T. (2017) *Uptake of GCSE subjects 2016*. Statistics Report Series No. 114. Cambridge, UK: Cambridge Assessment.

- Cassidy, R., Cattan, S., Crawford, C. & Dytham, S. (2019) How can we increase girls' uptake of maths and physics A-level? Available from <https://www.ifs.org.uk/publications/13277> [Accessed 13th August 2018]
- Celik, S. & Bayrakçeken, S. (2006) The effect of a 'Science, Technology and Society' course on prospective teachers' conceptions of the nature of science. *Research in Science & Technological Education*, 24 (2), 255 - 273.
- Chang Rundgren, S.-N. & Rundgren, C.-J. (2017) What are we aiming for?—A Delphi study on the development of civic scientific literacy in Sweden. *Scandinavian Journal of Educational Research*, 61 (2), 224-239.
- Chitty, C. (1991) *The Great Debate: the politics of the secondary school curriculum, 1976 -88*. Doctoral thesis , Institute of Education, University of London.
- Chitty, C. (2009) *Education policy in Britain, 2nd ed*. Basingstoke: Palgrave Macmillan.
- Coe, R., Waring, M., Hedges, L.V. & Arthur, J. (2012) *Research methods and methodologies in education*. Los Angeles: Sage.
- Cohen, L., Manion, L. & Morrison, K. (2007) *Research Methods in Education (6th Edition)*. Abingdon, Oxford: Routledge.
- Cohen, L., Manion, L. & Morrison, K. (2013) *Research Methods in Education (7th Edition)*. Abingdon, Oxford: Routledge.
- Cohen, L.J. (1992) *An Essay on Belief and Acceptance*. London: Oxford University Press.
- Connell, L. & James, W.S. (1958) General Science Today. *School Science Review*, XXXIX (138).
- Craig, E. (2005) Ontology. In E. Craig ed. *Shorter Routledge Encyclopaedia of Philosophy*. Abingdon: Routledge, 756 - 757.
- Crequer, N. (1989) HMI warns of teacher crisis in schools *The Independent*, March 1st 1989.
- Creswell, J.W. (2014) *Research design : qualitative, quantitative, and mixed methods approaches*. Fourth edition, international student edition.. ed.: Los Angeles: Sage.
- Cutts, D. & Russell, A. (2015) From coalition to catastrophe: the electoral meltdown of the Liberal Democrats. *Parliamentary Affairs*, 68 (suppl\_1), 70-87.
- Dalkir, K. (2013) *Knowledge management in theory and practice*. London: Routledge.
- Daugherty, R. (2004) *National Curriculum Assessment: a review of policy 1987-1994*. London: Routledge.
- Davies, M. (2015) Knowledge (Explicit, Implicit and Tacit): Philosophical Aspects A2 In Wright, James D. *International Encyclopedia of the Social & Behavioral Sciences (Second Edition)*. Oxford: Elsevier, pp. 74-90.
- Davis, J. (2002) The Inner London Education Authority and the William Tyndale Junior School Affair, 1974-1976. *Oxford Review of Education*, 28 (2/3), 275-298.

- DCSF (2007) *The National Curriculum: statutory requirements for key stages 3 and 4*. London: HMSO
- Dearing, R. (1994) *The National Curriculum and its Assessment: Final Report*. London: Hmso.
- DeBoer, G.E. (2000) Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of research in science teaching*, 37 (6), 582-601.
- Delamont, S., Beynon, J. & Atkinson, P. (1988) In the beginning was the Bunsen: the foundations of secondary school science. *International Journal of Qualitative Studies in Education*, 1 (4), 315-328.
- Demirdogen, B. & Uzuntiryaki-Kondakc, E. (2016) Closing the gap between beliefs and practice: Change of pre-service chemistry teachers' orientations during a PCK-based NOS course. *Chemistry Education Research and Practice. The Royal Society of Chemistry*.
- Denham, A. (2001) *Keith Joseph*. Chesham: Acumen.
- Denzin, N.K. (1989) *Interpretive biography*. Newbury Park: Sage.
- DES (1980) *A Framework for The School Curriculum: Proposals for Consultation*. London: HMSO.
- DES (1981) *The School Curriculum*. London: HMSO
- DES (1982) *Science Education in Schools*. London: HMSO
- DES (1985) *Science 5-16: A statement of policy*. London: HMSO.
- DES (1988a) *Education Reform Act*. London: HMSO.
- DES (1988b) *Science for Ages 5 to 16*. London: HMSO, 142.
- DES (1989) *Science in the National Curriculum*. London: HMSO.
- DES (1991a) *Science for ages 5-16 (Draft Consultation)*. London: HMSO.
- DES (1991b) *Science in the National Curriculum*. London: HMSO.
- DfE (1995) *Science in the National Curriculum*. London: HMSO.
- DfE (2015) *National curriculum in England: science programmes of study*. London: HMSO.
- DfEE (1999) *Science: The National Curriculum for England*. London: The Stationery Office
- DfES (2004) *Science: The National Curriculum for England*. London: The Stationery Office
- Donnelly, J. (2001) Contested terrain or unified project? 'The nature of science' in the National Curriculum for England and Wales. *International Journal of Science Education*, 23 (2), 181 - 195.
- Donovan, B.M., Moreno Mateos, D., Osborne, J.F. & Bisaccio, D.J. (2014) Revising the Economic Imperative for US STEM Education. *PLoS Biology*, 12 (1)

- Driver, R., Leach, J., Millar, R. & Scott, P. (1996) *Young people's images of science*. Buckingham: Open University Press.
- Drori, G.S. (2000) Science Education and Economic Development: Trends, Relationships, and Research Agenda. *Studies in Science Education*, 35 (1), 27-57.
- Eldredge, N. & Gould, S.J. (1972) Punctuated equilibria: an alternative to phyletic gradualism. In T.J.M. Schopf (ed.) *Models in Paleobiology*. San Francisco: Freeman Cooper
- Elo, S., Kääriäinen, M., Kanste, O., Pölkki, T., Utriainen, K. & Kyngäs, H. (2014) Qualitative Content Analysis. *A Focus on Trustworthiness*, 4 (1).
- Emery, H. (1998) A national curriculum for the education and training of teachers: an english perspective. *Journal of In-Service Education*, 24 (2), 283-291.
- Falk, J.H. & Dierking, L.D. (2012) Lifelong Science Learning fro Adults: The Role of Free-Choice Experiences. In B.J. Fraser, K.G. Tobin & C.J. McRobbie (eds.) *Second International Handbook of Science Education*. London: Springer
- Feyerabend, P.K. (1975) *Against Method*. London: Verso.
- Flick, U. (2009) *An Introduction to Qualitative Research*. London: Sage Publications Ltd.
- Forster, W. (1870) *Elementary Education Bill*. Hansard, 25 July 1870.
- Garnham, E. (2009) 'Dumbed down' GCSE science exams are far too easy [online]. Express Newspapers. Available from: <http://www.express.co.uk/news/uk/91580/Dumbed-down-GCSE-science-exams-are-far-too-easy> [Accessed August 1st 2016].
- Gill, T. & Bell, J.F. (2013) What factors determine the uptake of A-level physics? *International Journal of Science Education*, 35 (5), 753-772.
- Gillard, D. (2010) *Callaghan - Ruskin College speech 1976 - full text online* [online]. <http://www.educationengland.org.uk/documents/speeches/1976ruskin.html> [Accessed May 29th 2018].
- Gillard, D. (2016) *Education in England - Chapter 3* [online]. <http://www.educationengland.org.uk/history/chapter03.html> [Accessed June 30th 2018].
- Glaser, B.G. & Strauss, A. (1967) *The Discovery of Grounded Theory; Strategies for Qualitative Research* [online]. Aldine Transaction. Available from: [https://www.amazon.co.uk/s/?ie=UTF8&keywords=glaser+and+strauss+1967&tag=googhydr-21&index=stripbooks&hvadid=196717281323&hvpos=1t1&hvnetw=g&hvrnd=10381089267960937002&hvpone=&hvpstwo=&hvmqmt=e&hvdvcmdl=&hvllocint=&hvllocphy=1006565&hvtargid=kwd-315458687899&ref=pd\\_sl\\_7w47vajtuu\\_e\\_p28](https://www.amazon.co.uk/s/?ie=UTF8&keywords=glaser+and+strauss+1967&tag=googhydr-21&index=stripbooks&hvadid=196717281323&hvpos=1t1&hvnetw=g&hvrnd=10381089267960937002&hvpone=&hvpstwo=&hvmqmt=e&hvdvcmdl=&hvllocint=&hvllocphy=1006565&hvtargid=kwd-315458687899&ref=pd_sl_7w47vajtuu_e_p28) [Accessed January 20th 2018].
- Goodson, I.F. (2005) *Learning, Curriculum and Life Politics: The Selected Works of Ivor F. Goodson*. London: Routledge.
- Gove, M. (2009) *What is education for?* London: Royal Society of Arts.

- Greenhalgh, T. & Russell, J. (2006) Reframing Evidence Synthesis As Rhetorical Action in the Policy Making Drama. *Healthcare Policy*, 1 (2), 34-42.
- Greening, J. (2017) *Education Secretary announces first new T Levels* [online]. Department for Education. Available from: <https://www.gov.uk/government/news/education-secretary-announces-first-new-t-levels> [Accessed January 20th 2018].
- Gretton, J. (1976) *William Tyndale: collapse of a school or a system?* London: George Allen and Unwin Ltd.
- Hacieminoglu, E. (2014) In-service Teachers' Perceptions regarding their Practices related to Integrating Nature of Science: Case Study. *5th World Conference on Educational Sciences*, 116, 1268-1273.
- Haig, B.D. (2014) *Investigating the psychological world : scientific method in the behavioral sciences*. Cambridge, Massachusetts: The MIT Press.
- Hamel, J., Dufour, S. & Fortin, D. (1993) *Case study methods*. 32 32.
- Hansard (1868) House of Lords Debate 15 June 1868. Hansard: House of Lords, 1538 - 53.
- Harlen, W. (2001) Research in primary science education. *Journal of Biological Education*, 35 (2), 61-65.
- Harlen, W. (2014) *Assessment, standards and quality of learning in primary education*. Cambridge Primary Review Trust York.
- Harlen, W. & Holroyd, C. (1997) Primary teachers' understanding of concepts of science: impact on confidence and teaching. *International Journal of Science Education*, 19 (1), 93-105.
- HMI (1977) *Curriculum 11-16*. London: HMSO.
- HMI (1980a) *A View of the Curriculum*. London: HMSO.
- HMI (1980b) *Girls and Science*. London: HMSO.
- HMI (1981) *Curriculum 11-16: a review of progress*. London: HMSO.
- HMI (1983) *Curriculum 11-16: towards a statement of entitlement*. London: HMSO.
- HMI (1985) *The Curriculum from 5 to 16*. London: HMSO.
- Hodson, D. (1993) Philosophic stance of secondary school science teachers, curriculum experiences, and children's understanding of science: Some preliminary findings. *Interchange*, 24 (1), 41-52.
- Hodson, D. (2014) Nature of Science in the Science Curriculum: Origin, Development, Implications and Shifting Emphases. In M.R. Matthews (ed.) *International Handbook of Research in History, Philosophy and Science Teaching*. Dordrecht: Springer Netherlands, pp. 911-970.

- Holbrook, J. & Rannikmae, M. (2007) The nature of science education for enhancing scientific literacy. *International Journal of Science Education*, 29 (11), 1347-1362.
- House of Commons (2009) *House of Commons - Children, Schools and Families Committee - Fourth Report* [online].  
<http://www.publications.parliament.uk/pa/cm200809/cmselect/cmchilsch/344/34405.htm> [Accessed 29th May 2015].
- Hutchison, D. & Schagen, I.P. (1994) *How reliable is National Curriculum assessment?* NFER.
- Huxley, T.H. (1899) *Science and Education*. New York: D. Appleton and Company.
- IoP (2013) *The importance of Physics to Economic Growth*. London: Institute of Physics
- Irez, S. (2006) Are we prepared?: An assessment of preservice science teacher educators' beliefs about nature of science. *Science Education*, 90 (6), 1113-1143.
- James, E.L. (1972) *Teacher Education and Training*. London: HMSO.
- James, M., Oates, T., Pollard, A. & Wiliam, D. (2011) The Framework for the National Curriculum: A report by the Expert Panel for the National Curriculum review.
- Jenkins, E.W. (1979) *From Armstrong to Nuffield: Studies in Twentieth-century Science Education in England and Wales*. London: John Murray Publishers Ltd.
- Jenkins, E.W. (1996) The 'nature of science' as a curriculum component. *Journal of Curriculum Studies*, 28 (2), 137-150.
- Jenkins, E.W. (1998) The Association for Science Education and the struggle to establish a policy for school science in England and Wales, 1976–81. *History of Education*, 27 (4), 441-459.
- Jenkins, E.W. (1999) School science, citizenship and the public understanding of science. *International Journal of Science Education*, 21 (7), 703-710.
- Jenkins, E.W. (2000) The impact of the national curriculum on secondary school science teaching in England and Wales. *International Journal of Science Education*, 22 (3), 325-336.
- Jenkins, E.W. (2004) From option to compulsion: school science teaching 1954-2004. *School Science Review*, 85 (313), 33-40.
- Jenkins, E.W. (2007) School science: a questionable construct? *Journal of Curriculum Studies*, 39 (3), 265-282.
- Jenkins, E.W. (2016) *Sources and problems in the history of school science teaching* [online]. University of Leeds, School of Education. Available from:  
<http://www.leeds.ac.uk/educol/documents/000000187.htm> [Accessed April 5th 2016].
- Jenkins, E.W. (2019) *Science for All*. London: IOE Press.



- Jones, A. & Taub, L. (2019) *The Cambridge History of Science: Volume 1: Ancient Science*. 1 1, Cambridge: Cambridge University Press.
- Kagan, D.M. (1992) Implication of Research on Teacher Belief. *Educational Psychologist*, 27 (1), 65 - 90.
- Karakas, M. (2009) Cases of Science Professors' Use of Nature of Science. *Journal of Science Education and Technology*, 18 (2), 101 - 119.
- Kelly, A.V. (2009) *The Curriculum: Theory and Practice*. London: Sage Publications Ltd.
- Kingman, J. (1988) *Report of the Committee of Inquiry into the Teaching of English Language*. London: HMSO.
- Klein, P.D. (2005) Epistemology In E. Craig ed. *Shorter Routledge Encyclopaedia of Philosophy*. Abingdon: Routledge, pp. 224 - 227.
- Kohlbacher, F. (2006) The Use of Qualitative Content Analysis in Case Study Research. *Qualitative Social Research*, 7 (1 ).
- Kosso, P. (2009) The Large-scale Structure of Scientific Method. *Science & Education*, 18 (1), 33-42.
- Kosunen, S. & Hansen, P. (2018) Discursive narratives of comprehensive education politics in Finland. *European Educational Research Journal*, 17 (5), 714-732.
- Kremer, K., Specht, C., Urhahne, D. & Mayer, J. (2014) The relationship in biology between the nature of science and scientific inquiry. *Journal of Biological Education*, 48 (1), 1-8.
- Kuhn, T.S. (1996) *The Structure of Scientific Revolutions*. 3rd ed. Chicago: University of Chicago Press.
- Kvale, S. (1996) *InterViews : an introduction to qualitative research interviewing*. London : Sage Publications Ltd.
- Lawson, J. (1973) *A social history of education in England*. London: London : Methuen.
- Lawton, D. (1983) *The politics of educational research*. London: BERA.
- Lawton, D. (1986) The Department of Education and Science: policy making at the centre. In A. Hartnett & M. Naish (eds.) *Education and Society Today*. London: Falmer Press.
- Layton, D. (1974) *Science for the People*. London: Allen & Unwin.
- Layton, D. (1984) *Interpreters of Science: History of the Association for Science Education*. London: John Murray.
- Leaker, D. (2009) Unemployment trends since the 1970s. *Economic & Labour Market Review*, 3 (2), 37-41.
- Leary, B. (2013) *Oxford DNB article: Sharp, William* [online]. Oxford University Press. Available from: <http://www.oxforddnb.com/view/article/25223?docPos=3> [Accessed April 3rd 2016].

- Leden, L., Hansson, L., Redfors, A. & Ideland, M. (2015) Teachers' Ways of Talking About Nature of Science and Its Teaching. *Science & Education*, 24 (9), 1141-1172.
- Lederman, N.G. (1992) Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching*, 29 (4), 331-359.
- Lederman, N.G. (1999) Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of research in science teaching*, 36 (8), 916-929.
- Lederman, N.G. (2007) Nature of Science: Past, Present and Future. In S.K. Abell & N.G. Lederman (eds.) *Handbook of Research on Science Education*. Mahwah, New Jersey: Lawrence Erlbaum Associates, 831 - 879.
- Lederman, N.G., Abd-El-Khalick, F., Bell, R., L. & Schwartz, R.S. (2002) Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, 39 (6), 497-521.
- Lederman, N.G., Antink, A. & Bartos, S. (2014) Nature of science, scientific inquiry, and socio-scientific issues arising from genetics: A pathway to developing a scientifically literate citizenry. *Science & Education*, 23 (2), 285-302.
- Lederman, N.G., Lederman, J.S. & Antink, A. (2013) Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. *International Journal of Education in Mathematics, Science and Technology*, 1 (3).
- Lederman, N.G., Wade, P.D. & Bell, R.L. (1998) Assessing the Nature of Science: What is the Nature of Our Assessments? *Science & Education*, 7 (6), 595-615.
- Lederman, N.G. & Zeidler, D.L. (1987) Science teachers' conceptions of the nature of science: Do they really influence teaching behavior? *Science Education*, 71 (5), 721-734.
- Lee, Y.C. (2008) Exploring the Roles and Nature of Science: A case study of severe acute respiratory syndrome. *International Journal of Science Education*, 30 (4), 515 - 541.
- Lemos, N.M. (1999) Value Theory. In Audi, R. (ed.) *The Cambridge Dictionary of Philosophy*. Cambridge: Cambridge University Press, pp. 949 - 950.
- Lightfoot, L. (2010) The appliance of real science *The Independent*, p. 50.
- Lindberg, D.C. & Shank, M.H. (2013) *The Cambridge History of Science: Volume 2: Medieval Science*. 2 2, Cambridge: Cambridge University Press.
- Liu, S.-Y. & Lederman, N.G. (2007a) Exploring Prospective Teachers' Worldviews and Conceptions of Nature of Science. *International Journal of Science Education*, 29 (10), 1281 - 1307.
- Liu, S.-Y. & Lederman, N.G. (2007b) Exploring Prospective Teachers' Worldviews and Conceptions of Nature of Science. *International Journal of Science Education*, 29 (10), 1281 - 1307.

- Lowe, R. (1984) Robert Morant and the Secondary School Regulations of 1904. *Journal of Educational Administration and History*, 16 (1), 37-46.
- Macfarlane, E. (1993) Double award GCSE balanced science: its contribution to A-level success. *Physics Education*, 28 (6), 362.
- Mack, L. (2010) The Philosophical Underpinnings of Educational Research. *Polyglossia*, 19, 5 - 11.
- Maclure, S. (1989) Will we ever get the teachers we need? *The Times*, August 12th 1989.
- Magill, K. (1994) Against Critical Realism. *Capital & Class*, 18 (3), 113-136.
- McComas, W., Almazroa, F., Clough, H., Clough, M. & Clough, P. (1998) The Nature of Science in Science Education: An Introduction. *Contributions from History, Philosophy and Sociology of Science and Mathematics*, 7 (6), 511-532.
- McComas, W. & Olson, J. (2002) The Nature of Science in International Science Education Standards Documents. In McComas, W. ed. *The Nature of Science in Science Education*. Springer Netherlands, pp. 41-52.
- McComas, W.F. (ed.) (2002) *The Nature of Science in Science Education*, London: Kluwer.
- McComas, W.F., Clough, M.P. & Almazroa, H. (2002) The Role and Character of the Nature of Science in Science Education. In W.F. McComas ed. *The Nature of Science in Science Education: Rationales and Strategies*. Dordrecht: Springer Netherlands, pp. 3-39.
- McCulloch, G. (2006) Education and the Middle Classes: The Case of the English Grammar Schools, 1868–1944. *History of Education*, 35 (6), pp. 689-704.
- McNair, A. (1944) *Teachers and Youth Leaders: Report of the Committee appointed by the President of the Board of Education to consider the Supply, Recruitment and Training of Teachers and Youth Leaders*. London: HMSO.
- McPherson, G.R. (2001) Teaching & Learning the Scientific Method. *The American Biology Teacher*, 63 (4), 242-245.
- McSmith, A. (1994) *Kenneth Clarke : a political biography*. London: Verso.
- Mellado, V. (1997) Preservice Teachers' Classroom Practice and Their Conceptions of the Nature of Science. *Science & Education*, 6 (4), 331-354.
- Mihladić, G. & Dogan, A. (2014) Science teachers' views about NOS and the place of NOS in science teaching. *5th World Conference on Educational Sciences*, 116, pp. 3476-3483.
- Millar, F. (2013) Who is really behind Michael Gove's big education ideas? *The Guardian*, 3 December 2013.
- Millar, R. (2001) Towards a Science Curriculum for Public Understanding. In Amos, S. & Boohan, R. (eds.) *Teaching Science in Secondary Schools: A Reader*. Routledge, p. 304.
- Millar, R. (2007) Scientific Literacy. In Claessens, M. (ed.) *Communicating European Research 2005*. Dordrecht: Springer Netherlands, pp. 145-150.

- Millar, R. & Osborne, J. (1998) *Beyond 2000: science education for the future*. London: King's College London.
- Miller, M.C.D., Montplaisir, L.M., Offerdahl, E.G., Cheng, F.-C. & Ketterling, G.L. (2010) Comparison of Views of the Nature of Science between Natural Science and Nonscience Majors. *Cbe-Life Sciences Education*, 9 (1), 45-54.
- Monk, M. & Osborne, J. (2006) Placing the History and Philosophy of Science on the Curriculum. *Science Education: Science, education, and the formal curriculum*, 1, 109.
- Mulley, F. (1976) *School Education in England: problems and initiatives*. London: HMSO.
- NASUWT (2017) *Assessment without levels: taking stock*. London: NASUWT.
- Nelson, G.D. (1998) Science Literacy for all: an achievable goal? *Optics & Photonics News*, 9 (9).
- Nott, M. & Wellington, J. (1996) When the black box springs open: practical work in schools and the nature of science. *International Journal of Science Education*, 18 (7), 807 - 818.
- Nott, M. & Wellington, J. (1998) Eliciting, Interpreting and Developing Teachers' Understandings of the Nature of Science. *Science & Education*, 7 (6), 579-594.
- Nott, M. & Wellington, J. (1999) The state we're in: issues in key stage 3 and 4 science. *School Science Review*, 81, 13-18.
- Nye, M.J. (ed.) (2002) *The Cambridge History of Science: Volume 5: The Modern Physical and Mathematical Sciences*, Cambridge: Cambridge University Press.
- O'leary, Z. (2014) *The Essential Guide to Doing Your Research Project*. London: Sage Publications Ltd.
- OECD (2016) *PISA 2015 Assessment and Analytical Framework*. OECD Publishing.
- OFQUAL (2009) *The new GCSE science examinations: Findings from the monitoring of the new GCSE science specifications, 2007 to 2008*. London: Qualifications and Curriculum Authority.
- Osborne, J., Collins, S., Ratcliffe, M., Millar, R. & Duschl, R. (2003) What "ideas-about-science" should be taught in school science? - A Delphi study of the expert community. *Journal of Research in Science Teaching*, 40 (7), 692-720.
- Owen, J. (2018) T levels rejected by some of Britain's top universities *TES, February 9th 2018*.
- Ozgelen, S. & Yilmaz-Tuzun, O. (2012) A review on pre-service teachers' views on nature of science. *Energy Education Science and Technology Part B-Social and Educational Studies*, 4 (2), 603-616.
- Ozgelen, S., Yilmaz-Tuzun, O. & Hanuscin, D.L. (2013) Exploring the Development of Preservice Science Teachers' Views on the Nature of Science in Inquiry-Based Laboratory Instruction. *Research in Science Education*, 43 (4), 1551-1570.
- Pajares, M.F. (1992) Teachers' Beliefs and Educational Research: Cleaning Up a Messy Construct. *Review of Educational Research*, 62 (3), 307-332.

- Palmquist, B.C. & Finley, F.N. (1997) Preservice teachers' views of the nature of science during a postbaccalaureate science teaching program. *Journal of Research in Science Teaching*, 34 (6), 595-615.
- Park, K. & Daston, L. (2006) *The Cambridge History of Science: Volume 3: Early Modern Science*. Cambridge: Cambridge University Press.
- Pascall, D.L. (1991) *Curriculum Council Consultation Report: Science*. York.
- Paton, G. (2012) Government adviser attacks 'fatally flawed' curriculum. *The Telegraph*, 2012-06-12.
- Pinar, W.F. (2011) *What Is Curriculum Theory?* Abingdon: Routledge.
- Plowden, B.B.H. (1967) *Children and Their Primary Schools: A Report. Research and Surveys*. London: HMSO.
- Polanyi, M. (2009) *The Tacit Dimension*. Revised ed. Chicago: University of Chicago Press.
- Popper, K. (2002) *The Logic of Scientific Discovery*. Revised ed. London: Routledge.
- Porter, R. (ed.) (2003) *The Cambridge History of Science: Volume 4: Eighteenth-Century Science*, Cambridge: Cambridge University Press.
- Porter, T.M. & Ross, D. (eds.) (2003) *The Cambridge History of Science: Volume 7: The Modern Social Sciences*, Cambridge: Cambridge University Press.
- Posner, G.J. (2004) *Analyzing the curriculum*. London: McGraw-Hill.
- Priestley, M. (2011) Whatever happened to curriculum theory? Critical realism and curriculum change. *Pedagogy, Culture & Society*, 19 (2), 221-237.
- Puttick, S. (2015) Chief examiners as Prophet and Priest: relations between examination boards and school subjects, and possible implications for knowledge. *The Curriculum Journal*, 26 (3), 468-487.
- Reber, A.S. (1989) Implicit learning and tacit knowledge. *Journal of experimental psychology: General*, 118 (3), 219.
- Reiners, C.S., Bliersbach, M. & Marniok, K. (2017) The Cultural Argument for Understanding Nature of Science. *Science & Education*, 26 (5), 583-610.
- Richardson, H. (2017) *Legal threat over 'back door' grammars* [online]. BBCNews. Available from: <https://www.bbc.com/news/education-39589911>. Accessed on 15<sup>th</sup> May 2019
- Robbins, L.C. (1963) *Robbins Report 1963* London: HMSO.
- Roberts, D. (2007) Scientific Literacy/Science Literacy. In S.K. Abell & N.G. Lederman eds. *Handbook of Research on Science Education*. Mahwah, New Jersey: Lawrence Erlbaum Associates, 1330.
- Roberts, D.A. & Bybee, R.W. (2014) Scientific literacy, science literacy, and science education.

- Roberts, N. (2014) *National Curriculum Review*. London: House of Commons Library
- Robinson, J.T. (1968) *Science Teaching and the Nature of Science*. Belmont, California: Wadsworth Publishing Company, Inc.
- Robinson, J.T. (1998) Science Teaching and the Nature of Science (orig. 1965). *Science & Education*, 7 (6), 617-634.
- Ross, S. (1962) Scientist: The story of a word. *Annals of science*, 18 (2), 65-85.
- Roy, A. (1999) *The Role of Science and Technology in Society and Governance - Toward a New Contract between Science and Society* World Conference on Science
- Rudge, D.W., Cassidy, D.P., Fulford, J.M. & Howe, E.M. (2014) Changes Observed in Views of Nature of Science During a Historically Based Unit. *Science & Education*, 23 (9), 1879-1909.
- Rudolph, J.L. (2000) Reconsidering the 'nature of science' as a curriculum component. *Journal of Curriculum Studies*, 32 (3), 403-419.
- Russell, T., Qualter, A. & McGuigan, L. (1995) Reflections on the implementation of National Curriculum Science Policy for the 5-14 age range: findings and interpretations from a national evaluation study in England. *International Journal of Science Education*, 17 (4), 481-492.
- Sankey, H. (2016) *Scientific realism and the rationality of science*. London: Routledge.
- Sarieddine, D. & BouJaoude, S. (2014) Influence of Teachers' Conceptions of the Nature of Science on Classroom Practice. *Eurasia Journal of Mathematics Science and Technology Education*, 10 (2), 135-151.
- SATIS (1986) *Science and Technology in Science: Volume 1*. Hatfield: Association for Science Education.
- SCAA (1994) *Science in the National Curriculum (Draft Proposals)*. London: School Curriculum and Assessment Authority
- Schools Council (1981) *The practical curriculum*. London: HMSO.
- Scott, D. (2005) Critical Realism and Empirical Research Methods in Education. *Journal of Philosophy of Education*, 39 (4), 633-646.
- Shacklock, G. & Thorp, L. (2005) Life History and Narrative Approaches. In B. Somekh & C. Lewin (eds.) *Research methods in the social sciences*. London: Sage Publications Ltd. pp. 156-163.
- Shamos, M.H. (1995) *The Myth of Scientific Literacy*. New Brunswick, New Jersey: Rutgers University Press.
- Sharp, J.G. & Grace, M. (2004) Anecdote, opinion and whim: lessons in curriculum development from primary science education in England and Wales. *Research Papers in Education*, 19 (3), 293-321.

- Shen, B.S.P. (1975) Science literacy and the public understanding of science. *Communication of scientific information*. Karger Publishers, pp. 44-52.
- Shulman, L.S. (1986) Those who understand: knowledge growth in teaching. *Educational Researcher*, 4-14.
- Simon, B. (1992) The politics of comprehensive reorganization: a retrospective analysis. *History of Education*, 21 (4), 355-362.
- Simons, H. (2009) *Case Study Research in Practice*. London: Sage Publications Ltd.
- Smith, E.A. (2001) The role of tacit and explicit knowledge in the workplace. *Journal of knowledge Management*, 5 (4), 311-321.
- Smith, M.U., Lederman, N.G., Bell, R.L., McComas, W.F. & Clough, M.P. (1997) How great is the disagreement about the nature of science: A response to Alters. *Journal of Research in Science Teaching*, 34 (10), 1101-1103.
- Smithers, (2008) Schools. In Seldon, A. (ed.) *Blair's Britain: 1997 - 2007*. London: Cambridge University Press, pp. 361 - 384.
- Southerland, S.A., Johnston, A. & Sowell, S. (2006) Describing teachers' conceptual ecologies for the nature of science. *Science Education*, 90 (5), 874-906.
- Spradley, J.P. (1979) *The Ethnographic Interview*. Belmont, CA: Wadsworth Publishing Co Inc.
- Stake, R.E. (1995) *The Art of Case Study Research*. London: Sage Publications, Ltd.
- Stanley, W.B. & Brickhouse, N.W. (2001) Teaching sciences: The multicultural question revisited. *Science Education*, 85 (1), 35-49.
- Stark, S. & Torrance, H. (2004) Case Study. In S. Bridget & L. Cathy eds. *Research Methods in the Social Sciences*. London: Sage Publications Ltd, 376.
- Steele, G.R. (2005) Critical thoughts about critical realism. *Critical Review*, 17 (1-2), 133-154.
- Stone, D. (1997) *Policy Paradox: The Art of Political Decision Making*. New York: Norton.
- Sumranwanich, W. & Yuenyong, C. (2014) Graduate students' concepts of nature of science (NOS) and attitudes toward teaching NOS. *5th World Conference on Educational Sciences*, 116, 2443-2452.
- Swanborn, P. (2010) *Case Study Research: What, Why and How?* London: Sage Publications Ltd.
- Sweetman, J. (1994) National Curriculum: experimenting with science *The Guardian*, July 5th 1994, p. 11.
- Taber, K.S. (2008) Towards a Curricular Model of the Nature of Science. *Science & Education*, 17 (2), 179-218.
- Taber, K.S. (2014) Shifting the culture of science education to teach about the nature of science. *Teacher Development*, 18 (1), 124-133.

- Taber, K.S. (2017) Knowledge, beliefs and pedagogy: how the nature of science should inform the aims of science education (and not just when teaching evolution). *Cultural Studies of Science Education*, 12 (1), 81-91.
- Tairab, H.H. (2001) How do Pre-service and In-service Science Teachers View the Nature of Science and Technology? *Research in Science & Technological Education*, 19 (2), 235 - 250.
- Tang, X., Coffey, J.E., Elby, A. & Levin, D.M. (2009) The scientific method and scientific inquiry: Tensions in teaching and learning. *Science Education*, 94 (1), 29-47.
- Tattersall, K. (2007) A brief history of policies, practices and issues relating to comparability. *Techniques for monitoring the comparability of examination standards*, 42-96.
- Taylor, W. (2008) The James Report Revisited. *Oxford Review of Education*, 34 (3), 291-311.
- Tedder, M. (2012) Biographical Research. In R. Coe, M. Waring, L. Hedges & J. Arthur (eds.) *Research methods & methodologies in education*. Los Angeles: Sage Publications Ltd, pp. 285-293.
- Teresa Guerra-Ramos, M. (2012) Teachers' Ideas About the Nature of Science: A Critical Analysis of Research Approaches and Their Contribution to Pedagogical Practice. *Science & Education*, 21 (5), 631-655.
- Thatcher, M. (2011) *The Downing Street years*. London: Harper Press.
- Theocharis, T. & Psimopoulos, M. (1987) Where science has gone wrong. *Nature*, 329 (6140), 595-598.
- Thomas, G. (2011) *How to do your Case Study: A Guide For Students And Researchers*. London: Sage Publications Ltd.
- Thomas, G. (2016) *How to do your Case Study: A Guide For Students And Researchers*. Second edition. London: Sage Publications Ltd.
- Timmons, G. (2001) Science and science education in schools after the Great Exhibition. *Endeavour*, 25 (3), 109-120.
- Tobin, K. & McRobbie, C.J. (1997) Beliefs about the Nature of Science and the Enacted Science Curriculum. *Science & Education*, 6 (4), 355-371.
- Turner, J. (2012) It's Not Fair! *Primary Science Review*, No.121 (January).
- Tytler, D. (1989) Extra curriculum activities; Education *The Times (London)*, July 3rd 1989.
- Tytler, D. & Broom, D. (1988) Baker endorses extra science lessons *The Times (London)*, December 20th 1988.
- UNESCO (2017) *Different meaning of curriculum* [online]. UNESCO. Available from: <http://www.unesco.org/new/en/education/themes/strengthening-education-systems/quality-framework/technical-notes/different-meaning-of-curriculum/> [Accessed February 15th 2018].



- Van Dijk, E.M. (2014) Understanding the Heterogeneous Nature of Science: A Comprehensive Notion of PCK for Scientific Literacy. *Science Education*, 98 (3), 397-411.
- Wan, Z.H., Wong, S.L. & Zhan, Y. (2013) Teaching Nature of Science to Preservice Science Teachers: A Phenomenographic Study of Chinese Teacher Educators' Conceptions. *Science & Education*, 22 (10), 2593-2619.
- Weale, S. & Adams, R. (2019) 'It's dangerous': full chaos of funding cuts in England's schools revealed *The Guardian*.
- Webb, P. (2010) Science Education and Literacy: Imperatives for the Developed and Developing World. *Science*, 328 (5977), 448-450.
- Wellington, J. & Osborne, J. (2001) *Language and Literacy in Science Education*. Milton Keynes: Open University Press.
- West, A. (2015) Education policy and governance in England under the Coalition Government (2010–15): Academies, the pupil premium, and free early education. *London Review of Education*, 13 (2), 21-36.
- Weston, C. (1989) Education reforms 'at risk': Inspectors warn on teacher shortage consequences *Guardian*, March 1st 1989.
- Wilby, P. (1989) British schools may stay bottom of science league *The Independent*, January 7th 1989, p.3.
- Williams, J.D. (2008a) The Scientific Method and School Science. *Journal of College Science Teachers*, 38 (1).
- Williams, J.D. (2008b) What makes 'science' science? *The Scientist*, 22 (10), 29.
- Williams, J.D. (2009) Belief versus acceptance: Why do people not believe in evolution? *Bioessays*, 31 (11), 1255-1262.
- Williams, J.D. (2011) *How Science Works: Teaching and Learning in the Science Classroom*. Paperback ed. London: Continuum Books.
- Williams, J.D. (2013) "It's just a theory": trainee science teachers' misunderstandings of key scientific terminology. *Evolution: Education and Outreach*, 6 (1), 12.
- Williams, J.D. (2016) It's time to stop believing scientists about evolution. *School Science Review*. 98 (363). pp. 123-126.
- Wivagg, D. (2002) The Dogma of "The" Scientific Method. *The American Biology Teacher*, 64 (9), 645-646.
- Wolpert, L. (2004) *Prof Lewis Wolpert debates Therapeutic cloning* [online]. Y Touring Theatre Company. Available from: <http://www.geneticfutures.com/ltltg/info/sheet9.asp> [Accessed November 10th 2009]
- Woolnough, B., E. (1994) Why students choose physics, or reject it. *Physics Education*, 29 (6), 368.

Wrigley, T. (2014) Curriculum Change in English Schools: Educating Working-Class Children. *Social and Education History* 3 (3).

Yin, R.K. (2013) *Case Study Research: Design and Methods (Applied Social Research Methods)*. London: Sage Publications, Ltd.

Zeidler, D.L. & Lederman, N.G. (1989) The effect of teachers' language on students' conceptions of the nature of science. *Journal of Research in Science Teaching*, 26 (9), 771-783.

Ziman, J. (1996) Is science losing its objectivity? *Nature*, 382 (6594), 751-754.

## **Appendix A**

### **Index of Reports, Education Acts and Curriculum documents used within the case study**

The following appendices list, in alphabetical order, the various education acts, education reports and curriculum documents used in the document analysis and reviews of documentation for this thesis. The index provides brief summaries of the contents (except in the case of the curriculum documents) and the page number within the thesis where the report is mentioned or discussed.

### **Appendix A1: Education Acts**

#### **Index of Education Acts cited**

Education Act (1902) - Balfour Act: Secondary Education is established and Local Education Authorities replaced School Boards.....	17, 21
Education Act (1918) - Fisher Act: School leaving age raised to 14. Prohibition of Child Employment, Vocational training for 14-18 year olds made available .....	17, 22
Education Act (1936) - School leaving age raised to 15 (not fully enacted) .....	17
Education Act (1944) - Butler Act: Tripartite education; school leaving age raised to 15; all property and functions of 'boards of education' transferred to the Minister; LEAs legally obliged to secure education provision .....	17, 23, 27, 34
Education Act (1964) - Boyle Act: Creation of Middle Schools.....	17
Education Act (1968) - Changes to the 'character' of schools (to comprehensive) allowed.....	17
Education Act (1976) - The comprehensive principle is installed) .....	17
Education Act (1979) - repeal of the 1976 act, abolishing the 'comprehensive principle' .....	17
Education Reform Act (1988) - The National Curriculum; Foundation subjects and key stages; Duty to establish the National Curriculum by order; Courses leading to external qualifications; Local Management of Schools; Grant Maintained Status .....	8, 23, 80, 114, 118
The McNair Report (1944) Teachers and Youth Leaders The Stationery Office.....	32

## Appendix A2: Education reports and reviews

### Index of Education Reports cited

British Association for the Advancement of Science (1867) <i>Scientific Education in Schools</i> .....	14, 24
Callaghan, J (1976) <i>Ruskin Speech</i> Ruskin College Oxford - 18th October 99, 100, 101, 104, 108, 111, 123	
DES, (1980) <i>A Framework for The School Curriculum: Proposals for Consultation</i> . London: HMSO. ....	106
HMI (1980) <i>A view of the Curriculum</i> - 'Curriculum Matters' .....	104
HMI (1980) <i>Girls in Science</i> - curriculum matters .....	104, 105
HMI, (1985) <i>The Curriculum from 5 to 16</i> . London: HMSO. ....	107
Schools Council, (1981) <i>The practical curriculum</i> . London: HMSO. ....	107
Taunton Commission (1868) <i>Report of the Schools Inquiry Commission Vol I</i> London: HMSO. ....	16, 21
The first 'Red Book': curriculum 11-16 .....	101
<i>The Red Book (no.2)</i> (1981) <i>Curriculum 11-16: a review of progress</i> : reported on a study of 41 schools in five local authorities (that) worked with a group of HMI and advisers from the LEAs to re-examine their thinking about the curriculum. ....	103
The Robbins Report (1963) Higher Education: recommended an increase in HE provision and that ITT should be an HE course .....	32
The Yellow Book (1976) an internal document prepared for politicians about the state of education in England and Wales. ....	98, 99

## Appendix A3: Curriculum documents

### Index of National Curriculum Documents cited

DCSF, (2007) The National Curriculum: statutory requirements for key stages 3 and 4. London: HMSO, .....	159, 160
DES, (1989) Science in the National Curriculum London: HMSO (First enacted curriculum) .....	12, 132, 136, 137, 139
DES, (1991) Science for Ages 5-16 (draft) London: HMSO .....	143
DES, (1991) Science in the National Curriculum London: HMSO enacted, revised version with 4 ATs .....	143, 145, 148, 149
DfE, (1995) Science in the National Curriculum London: HMSO (post Dearing enacted version) .....	149
DfEE, (1999) Science: the National Curriculum for England London: The Stationery Office .....	153, 154, 156
DfES, (2004) Science: the National Curriculum for England London: HMSO (revised (KS4 only) version of the 1999 curriculum) .....	157
SCAA, (1994) Science in the National Curriculum: (draft proposals). London: School Curriculum and Assessment Authority .....	149

## Appendix B: Sample Document Analysis Record

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### Nature of Science: Document Analysis Record

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<b>Document Title</b>	The National Curriculum and its Assessment
<b>Document Origin</b>	SCAA - Report
<b>Authors</b>	Ron Dearing
<b>Document Date</b>	December 1993
<b>Intended Audience</b>	SoS for Ed, Teachers, Education Experts, Curriculum developers, Examination boards.
<b>Contextual Information</b>	<p>The report was commissioned by the DES (John Patten) as an urgent review of the N in its entirety. 4 main TORs:</p> <ul style="list-style-type: none"> <li>• Scope for slimming curriculum</li> <li>• How testing and central admin for NC can be improved</li> <li>• How testing can be simplified.</li> <li>• Future of the 10 level scale.</li> </ul>
<b>Document Purpose</b>	Government review report on NC
<b>Document Content</b>	<p>An extensive (107 page) report that looked at the relatively new curriculum and sort to produce a more workable curriculum structure and administration. The review was ordered by SoS Patten after great unrest with teachers about the sheer bulk of the new NC and the amount of content to be delivered.</p> <p>It looked also at testing – this came at a point when SATs were being developed e.g. CATS/MATs and Tasks in science (King's College). This report was a follow up to an interim (1993) report (unavailable). Main conclusions:</p> <ul style="list-style-type: none"> <li>• Reduce amount of content to be covered by law</li> <li>• Simplify PoS</li> <li>• Reduce 'prescription' to give teachers more freedom/scope</li> </ul> <p>It sought out the views of teachers education experts and others (e.g. employers) so it was a wide ranging review that took a variety of viewpoints on board.</p> <p>In terms of assessment –the 10 levels was 'prescriptive' as noted, and the notion of the 10 levels at KS4 flawed as we already had GCSE grades at KS4. Suggested maintaining the GCSE and not keeping 10 levels. Said that there was an issue for low attaining children – just suggested being looked at urgently! (p.71)</p>

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<b>Document Deficiencies</b>	<p>As reports go, it was thorough and did the job asked of it.</p> <p>Fails to look carefully at WHY we teach key subjects and accepts the premise that the way in which the subject structures (particularly pertinent to science) are set up is 'correct'. Although the report does not set out to challenge such structures it would have been one way to have looked at the task of reducing and simplifying.</p> <p>Set out a timetable for reform that was far too ambitious given the fundamental issues being looked at.</p> <p>There was also conflict in that he recommended keeping KS tests (SATS) BUT also that TA was important – that caused conflict in real life as schools mistrusted teacher assessment but the SATs were not necessarily fit for purpose.</p>
<b>Document Classification</b>	Government Report/ Report from a Government appointed body (independent, but linked)
<b>Document format</b>	A4 Published booklet
<b>Document reliability</b>	Reliable and a key document when considering the history of changes in the NC for science and the NC overall.
<b>Document references</b>	Ref/com/94/039

### Document Location Details

URL:

<http://www.educationengland.org.uk/documents/dearing1994/dearing1994.html>

Library Location: N/A – personal document collection

Computer Location: N/A

Endnote Entry: **Yes**

Endnote Upload: **No**

## Appendix C: Interview Schedule

### Question Schedule (PhD field research)

#### **Notes:**

The questions listed comprise core questions (to be asked of all interviewees) and suggested supplementary questions if the opportunity arises. Some supplementary questions will emerge from the interview taking a lead from the replies provided by the interviewee. These questions may vary from person to person.

All interviews will be recorded digitally. Some data (e.g. background detail) will not be used in the analysis other than to provide background information and allow the researcher to temporally place the interviewee with respect to the science national curriculum in use during the period they were in school.

*Core questions are in italics*

supplementary questions are indented

#### **Background detail**

Date of Birth

Qualifications

Type of School attended:

Primary

Secondary

#### **Memories of Science (home/primary/secondary)**

*Reflecting back, what's your earliest memory of 'doing' science either at home, in school?*

*Why do you think that what you were doing is 'science'?*

*What is your earliest memory of doing 'science' in school?*

*Did you know it was science?*

*What is your earliest memory of science in a secondary school setting?*

#### **Reasons for 'doing' science**

*Why did you choose to pursue a career/degree in 'science'?*

What is it about 'science' that motivates/captivates/engages you?

What motivated you to train to teach science after working in X

*What, for you is the purpose of science?*

*What sort of questions can science answer?*

*What can it not answer?*

What, in your view is science and what makes it different from other disciplines such as history or English?

In what ways do you think science is similar to say 'art'?



## **Descriptions of science/the scientific method**

*What methods do we usually employ to answer scientific questions?*

*What is the 'scientific method'? How would you describe this?*

*What do you think makes a good 'scientific question'?*

*What are the limits, in your view, of scientific knowledge?*

## **Science in life and science in society**

*How does science work in real life?*

Tell me about some aspect of science that has caught your attention recently.

Did you manage to bring this into your teaching?

What could prevent you from bringing in such contexts?

How issues do you think there are when explaining science to: Adults? Children?

Do you think that 'science' is thought of the same way the world over?

Do you think science may have different social and cultural identities in different countries?

*Should we automatically accept the findings of other scientists?*

What conditions would you impose on this?

Should science be solely about improving how people live and looking after our planet?

## **The language of science related to the NoS**

*What do you think the purpose and definition of a hypothesis is in science?*

*What, in your view is a scientific theory*

Does this definition apply to all scientific disciplines?

*What do you think is the status of a Law in science?*

How do ideas in science become 'laws'?

*Is a scientific principle the same as a law?*

In what way is it different or the same?

## **How scientists work/how science works**

*Do you think scientists have ideas first and find evidence to support them or do we generate ideas from observations?*

*Do you think that science has limits on what it can discover or explain?*

Do you think there is any scientific merit in things such as parapsychology, homeopathy, astrology, epigenetics, cold water fusion etc.?

*Do you think scientists naturally sceptical?*

*Should scientists be willing to change their ideas on things?*

What could prompt a scientist to change their mind?

## **Final Checks**

*Is there anything you would like to add to the discussion or any clarifications you wish to make about any answers you have provided for me?*

*Are you still happy for me to use this discussion in my thesis?*

## Appendix D: Information for Participants and Informed Consent

### Research Project



### Information for Participants

**Full title of Project:** Trainee Science Teachers and their Understanding of the Nature of Science  
**Researcher's Name:** James Williams, Lecturer in Education, School of Education and Social Work

#### Project Outline

This project is investigating views on the Nature of Science of trainee science teachers. The project is a case study of the development of the National Curriculum for Science over time, from its inception to the present day. It concentrates on those aspects of the curriculum that cover the 'Nature of Science'.

The project analyses Government policy, statutory legislation, background reports and publications as well as draft and published/implemented versions of the National Curriculum for Science since 1980. In addition, the project will interview a small group of trainee science teachers across the various science disciplines to elicit their views and understanding of the Nature of Science. In taking part in any interview, the identity of the interviewee will only be known to the researcher, James Williams. The interviews will be recorded (audio and/or video) and transcribed. Each interviewee will be allocated a unique ID. Any transcriptions or reference to any of the transcribed conversations will only be identified by the unique ID name/number. At the end of the research project the original recordings will be digitally erased and any written records of the personal data of interviewees (e.g. name, subject, date of birth etc.) will be securely shredded and disposed of.

Before the interview takes place, you will be asked to read, initial and sign a Participant agreement form. **Your participation in this project is voluntary.** You may, at any point (even after signing the agreement) withdraw from the project, ask for your details and any recordings made to date to be erased/destroyed or, before the final report is completed, for any contributions being considered to be withdrawn.

Having read this statement about the project, I am happy to answer any questions that you may have about the project and the intended outcomes (a thesis and associated academic articles for publication in peer reviewed and other journals).

#### Security of the participant data and recordings

Any participant data and/or digital recording (audio and/or video) will only be held on a secure personal laptop (protected by password entry) or on the University system, again protected by password entry. Only the researcher will have access to the raw data/recordings. The names of interviewees and the unique ID assigned to them will, again, only be known by the researcher.

**James D. Williams**  
**Lecturer in Education**

## Appendix D1: Informed Consent



### RESEARCH ETHICS:

**Full title of Project:** Trainee Science Teachers Understanding of the Nature of Science

**Researcher's Name:** James Williams, Lecturer in Education, School of Education and Social Work

Please Initial Box

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions.
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving reason.
3. I agree to take part in the above study.
4. I agree to the interview being audio recorded
5. I agree to the use of **anonymised** quotes in publications


\_\_\_\_\_  
Name of Participant

\_\_\_\_\_  
Date

\_\_\_\_\_  
Signature

James D. Williams

A handwritten signature in black ink, appearing to read 'James D. Williams', with a small dot at the end.

\_\_\_\_\_  
Name of Researcher

\_\_\_\_\_  
Date

\_\_\_\_\_  
Signature

## Appendix E: Interview Extract

### Transcript Extract

The following extract comes from the full transcript of 'Sophie's interview'

**JDW:**

OK, OK, right. Do you think that applies across all the disciplines so do you think that in general scientists have the same idea about what a theory is regardless of whether you're a chemist, geologist, a psychiatrist, a physicist?

**SOPHIE:**

It depends on... That's tricky, the thing is physicists have bigger theories that may be harder for them to prove. But I'm thinking about when we use the word theory when you talk about that when you talk about enzymes and the lock and key theory but some people say the lock and key mechanism so, is it really a theory because it is but maybe we just use that terminology from, could be twenty years ago and we didn't quite have evidence to back it up. I'm trying to think where else we use the words theory, well the theory of evolution

**JDW:**

so do you think that's... You said that it's not necessarily proven, do you think evolution is not necessarily proven?

**SOPHIE:**

I think there's enough evidence to prove evolution

**JDW:**

OK. Theory of plate tectonics. You might have done some of that?

**SOPHIE:**

Yeah I think that's maybe it's a to do with technology I think that it's proven when the tectonic plates that move

**JDW:**

atomic theory?

**SOPHIE**

that's hard to prove isn't that by trying...

**JDW:**

Gravity?

**SOPHIE:**

So you can see the effects of gravity but you can't prove gravity is there, so maybe it has to do with the when you can see the ef... It's difficult isn't it.

**JDW:**

You know it's something that you might want to think about. Yeah but what about the laws in science, we've got laws of gravity. You know, you've got gas laws but Hook's law.

**SOPHIE:**

Yeah, yeah.

**JDW:**

And about what about the status of those?

**SOPHIE:**

In my experience you know, in science it's usually like mathematical, a law. So there's usually very few exceptions you know and that's few exceptions to the rule. And then are these just words that scientists have added to a theory or that said this is my law. This is the law someone else maybe

**JDW:**

but I was just going to ask you that what you think is there a link between things like hypothesis and theory and law.

**SOPHIE:**

Yeah I think there can be a link.

**JDW:**

OK how might you describe that link.

**SOPHIE:**

I suppose a hypothesis is something that you're testing that's an idea a theory is an idea or something that's been tested or is or has been shown maybe and a law has usually been proven or works every time.

**JDW:**

So do you think there's like a... it's hierarchical. From a low base, to start with hypothesis move to theory?

**SOPHIE:**

We have to look... So yeah that seems like things are that way but yeah

**JDW:**

I'll chuck another one in principle

**SOPHIE:**

Principles. I'd say it's more like oh. I don't know, but I'm thinking it's more like theory. Then it's principles and usually. I think between theory and law, like it's been tested. It is really tricky Maybe that's why you don't think about these things at Key Stage 3.

**JDW:**

How do you think ideas in science become laws.

**SOPHIE:**

I suppose it's easy being tested enough or shown enough that someone says that's the law and that but having it there, it becomes ah, universally accepted.

**JDW:**

So just to keep an eye on time. So Do you think science should be really only about improving people's lives looking after a planet as we talked a little bit earlier about you know its purpose of science is that the main purpose of really why we do science what you think there's another element too.

**SOPHIE:**

I think there's another element. I think. Today there was always like Mystery in the wilds and people, it's fun to understand the answer to that mystery yes. It's you, that always try and figure out why.

**JDW:**

So even if there's no immediate, obvious benefit. To solving this mystery. You still think we should do it anyway

**SOPHIE:**

I think people would find a way to get passionate about it.

**JDW:**

And do you think scientists should be willing to change their ideas about things like...

**SOPHIE:**

Yeah, yeah yeah yeah.

**JDW:**

What should prompt them to change the mind. If you've got somebody who I don't know has one view of scientific phenomenon. What is it that prompts them to change their mind about that and go with a different view

**SOPHIE:**

I think it should be based on evidence. Yeah. Based on evidence. Maybe some kind of discourse a discussion about which evidence is more robust but still has scientific rigour and is tricky there is no.

**JDW:**

Interesting because my... my last question... Was how does science work in real life? Do we have ideas first and find evidence to support them or do we generate ideas from observations

**SOPHIE:**

I think it's probably a bit of a the both? I think it depends if this is about scientific disciplines or fields and where you are where you are placed.

**JDW:**

And have you come across the terms to deductive and inductive. Yeah. If you got any understanding as I say, do you know how you apply those

**SOPHIE:**

I think deductive is reasoning based on what you've seen. OK I'm not sure I would know inductive...

**JDW:**

And have you come across any historians and philosophers of science. You remember any of them?

**SOPHIE:**

No, not really?

**JDW:**

Popper?

**SOPHIE:**

No.

**JDW:**

Feyerabend?

**SOPHIE:**

No.

## Appendix F: Thematic Content Analysis Example

This appendix provides one example of an initial round of coding and analysis in the thematic content analysis. This was an iterative, reductive process to generate the final core themes for the interview analysis.

Themes	Sources	References
Scientific method	3	15
Pseudoscience	4	13
Laws	3	12
Proof, prove or proven	4	12
Hypothesis	4	11
Trust in Scientists	4	11
Scientific questions	4	10
First Memory	3	9
Scientific facts or facts	3	9
Evidence in Science	2	8
Laboratory classroom	3	7
Rigor	2	7
Science and ethics	2	7
Scientific language	3	7
Science and truth	1	6
Global warming	1	5
Science and creativity	1	5
Science and morals	1	5
Science as discovery of how things work	3	5
Theories and testing	3	5
Laws in Physics	2	4
Principle	3	4
Principle not a law	3	4
Purpose of science	2	4



Themes	Sources	References
Science and Mathematics	2	4
science explanation	1	4
Tests and Testing	2	4
Evidence leads to theories	1	3
First memory not educational	1	3
Inductive approach to science	2	3
Science and communication	3	3
Science and law	1	3
Science and predictions	2	3
Science and scepticism	1	3
Science as abstract ideas	2	3
Science defined as practical	2	3
Science in the media	3	3
Scientific limits	2	3
Theories as unproven	2	3
Deductive approach	2	2
Helping people or humanity	1	2
Hierarchy	1	2
History of Science	2	2
Hypothesis from theory	1	2
Investigation or investigations	2	2
Laws in Biology	1	2
Nature of scientific theories	2	2
No primary science	2	2
Not all scientists trusted	1	2
Placebo effect	1	2
Protocols	2	2
Science and bias	2	2

Themes	Sources	References
Science and fun	2	2
Social Context of science	2	2
Theories as explanations	1	2
Theory as an idea	1	2
Variables and science	1	2
Human endeavor	1	1
Laws and Chemistry	1	1
Limits of science	1	1
Philosophy and Science	1	1
Science as a tool for other subjects	1	1
Science in the Media unused	1	1
Science not creative	1	1
Science protocols	1	1
Science week	1	1
Scientific laws as mathematical	1	1
Principle as same as a law	0	0
Science with bias	0	0

**Round 1 themes: frequency count**

**Round 2 analysis:**

<b>Theme and Sub-Theme</b>	<b>Sources</b>	<b>References</b>
<b>Scientific method</b>	3	15
Hierarchy	1	2
Protocols	2	2
Rigour	2	7
Science protocols	1	1
Scientific questions	4	10
Tests and Testing	2	4
<b>Pseudoscience</b>	4	13
Placebo effect	1	2
<b>Laws</b>	3	12
Laws and Chemistry	1	1
Laws in Biology	1	2
Laws in Physics	2	4
Science and law	1	3
Scientific laws as mathematical	1	1
<b>Hypothesis</b>	4	11
Hypothesis from theory	1	2
<b>Trust in Scientists</b>	4	11
Not all scientists trusted	1	2
<b>First Memory</b>	3	9
First memory not educational	1	3
Laboratory classroom	3	7
No primary science	2	2
Science and fun	2	2
<b>Scientific language</b>	3	7
Science and truth, proof or proven	4	18
Science and creativity	1	5
Science not creative	1	1
<b>Principle</b>	3	4
Principle as same as a law	0	0
Principle not a law	3	4

Theme and Sub-Theme	Sources	References
Purpose of science	2	4
Helping people or humanity	1	2
Science as discovery of how things work	3	5
Science and maths	2	4
Inductive approach to science	2	3
Deductive approach	2	2
Science and communication	3	3
Science in the media	3	3
Science in the Media unused in teaching	1	1
Science and predictions	2	3
Science and scepticism	1	3
Science as abstract ideas	2	3
Science defined as practical	2	3
Control experiment	1	2
Investigation or investigations	2	2
Variables and science	1	2
History of science	2	2
Science and bias	2	2
Social Context of science	2	2
Global warming	1	5
Human endeavour	1	1
Science and ethics	2	7
Science and morals	1	5
Science as a tool for other subjects	1	1
Science week	1	1
Scientific limits	3	4
Philosophy and science	1	1
Scientific Data		
Evidence in Science	2	8
Evidence leads to theories	1	3
Science explanation	1	4

Theme and Sub-Theme	Sources	References
Scientific facts or facts	3	9
Theory		
Nature of scientific theories	2	2
Theories and testing	3	5
Theories as explanations	1	2
Theories as unproven	2	3
Theory as an idea	1	2

**TCA Reduction process generating broad themes & sub-themes from the round 1 analysis (number of references to main theme)**

(Note: Themes are shaded grey, sub-themes have no shading)

### Theme cluster analysis

The themes and sub-themes (above) were grouped together to form theme clusters for ease of analysis. Each cluster is considered again and participant responses re-analysed.

---

#### Cluster Name

---

- 1, Scientific Terminology
  2. Scientific Method, 'practical work', experiments, inductive and deductive approaches
  3. Social Context of Science
  4. Science and Communication
  5. Science, pseudoscience and scepticism
  6. Scientific questions and explanations
  7. History and Philosophy of Science
  8. Science and Creativity
- 

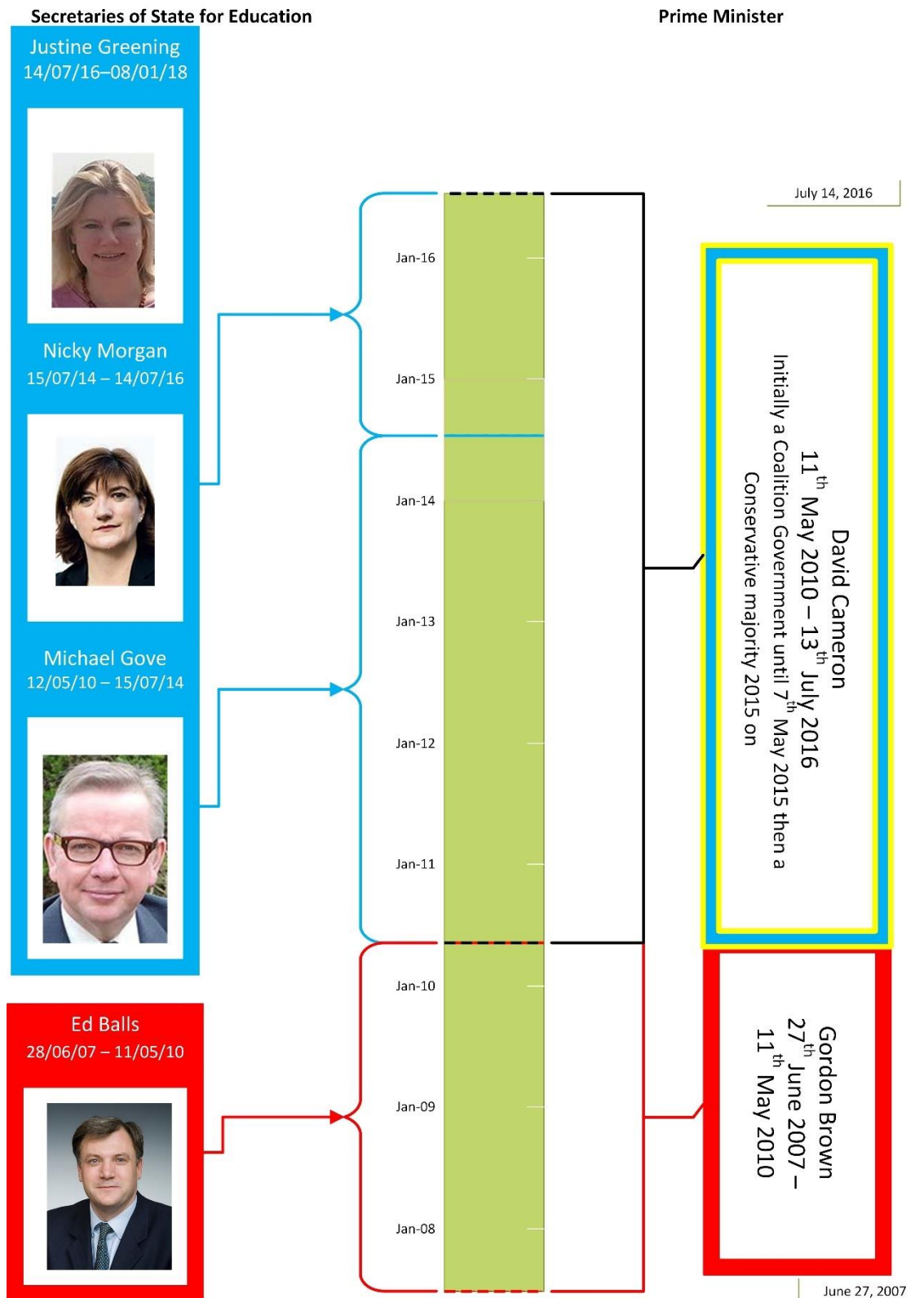
The interviews went through several phases on analysis to define and refine the various themes and theme clusters.

## Appendix G: Ethical Application Certificate of Approval



Certificate of Approval	
<b>Reference Number</b>	ER/JDW29/1
<b>Title Of Project</b>	Trainee Science Teachers understanding of the Nature of Science
<b>Principal Investigator (PI):</b>	James Williams
<b>Student</b>	James Williams
<b>Collaborators</b>	
<b>Duration Of Approval</b>	n/a
<b>Expected Start Date</b>	31-Oct-2015
<b>Date Of Approval</b>	30-Nov-2015
<b>Approval Expiry Date</b>	31-Aug-2016
<b>Approved By</b>	Jayne Paulin
<b>Name of Authorised Signatory</b>	Janet Boddy
<b>Date</b>	30-Nov-2015
<p>*NB. If the actual project start date is delayed beyond 12 months of the expected start date, this Certificate of Approval will lapse and the project will need to be reviewed again to take account of changed circumstances such as legislation, sponsor requirements and University procedures.</p> <p><b>Please note and follow the requirements for approved submissions:</b></p> <p>Amendments to protocol</p> <ul style="list-style-type: none"> <li>* Any changes or amendments to approved protocols must be submitted to the C-REC for authorisation prior to implementation.</li> </ul> <p>Feedback regarding the status and conduct of approved projects</p> <ul style="list-style-type: none"> <li>* Any incidents with ethical implications that occur during the implementation of the project must be reported immediately to the Chair of the C-REC.</li> </ul> <p>Feedback regarding any adverse and unexpected events</p> <ul style="list-style-type: none"> <li>* Any adverse (undesirable and unintended) and unexpected events that occur during the implementation of the project must be reported to the Chair of the Social Sciences C-REC. In the event of a serious adverse event, research must be stopped immediately and the Chair alerted within 24 hours of the occurrence.</li> </ul>	

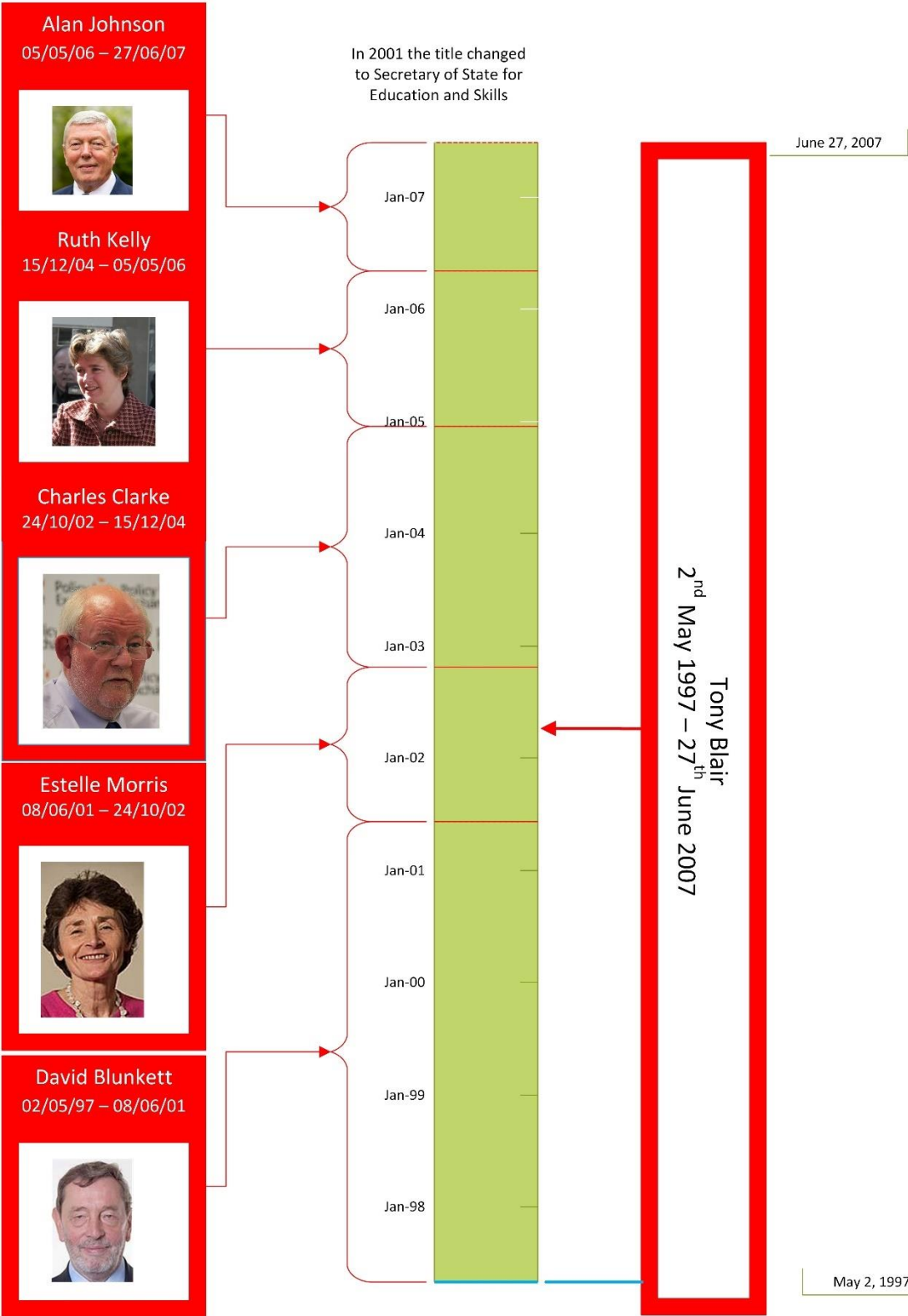
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Secretaries of State for Education

Prime Minister



Secretaries of State for Education

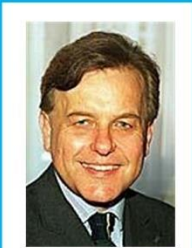
Prime Minister

In 1995 the title changed to Secretary of State for Education and Employment

Gillian Shephard  
20/07/94 – 02/05/97



John Patten  
10/04/92 – 20/07/94



Kenneth Clarke  
02/11/90 – 10/04/92



Jan-97

Jan-96

Jan-95

Jan-94

Jan-93

Jan-92

Jan-91

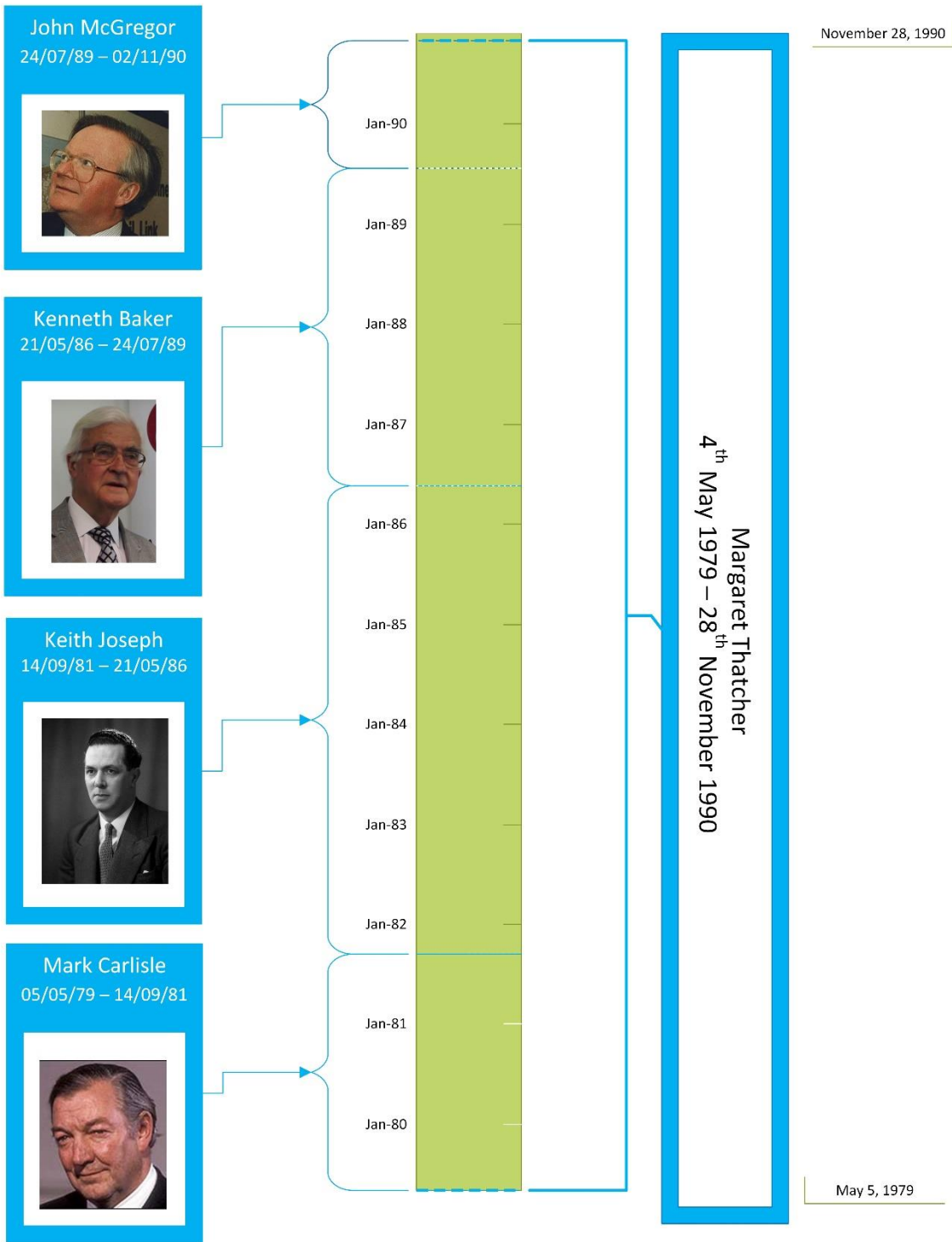
May 2, 1997

John Major  
28<sup>th</sup> November 1990 – 2<sup>nd</sup> May 1997

November 2, 1990

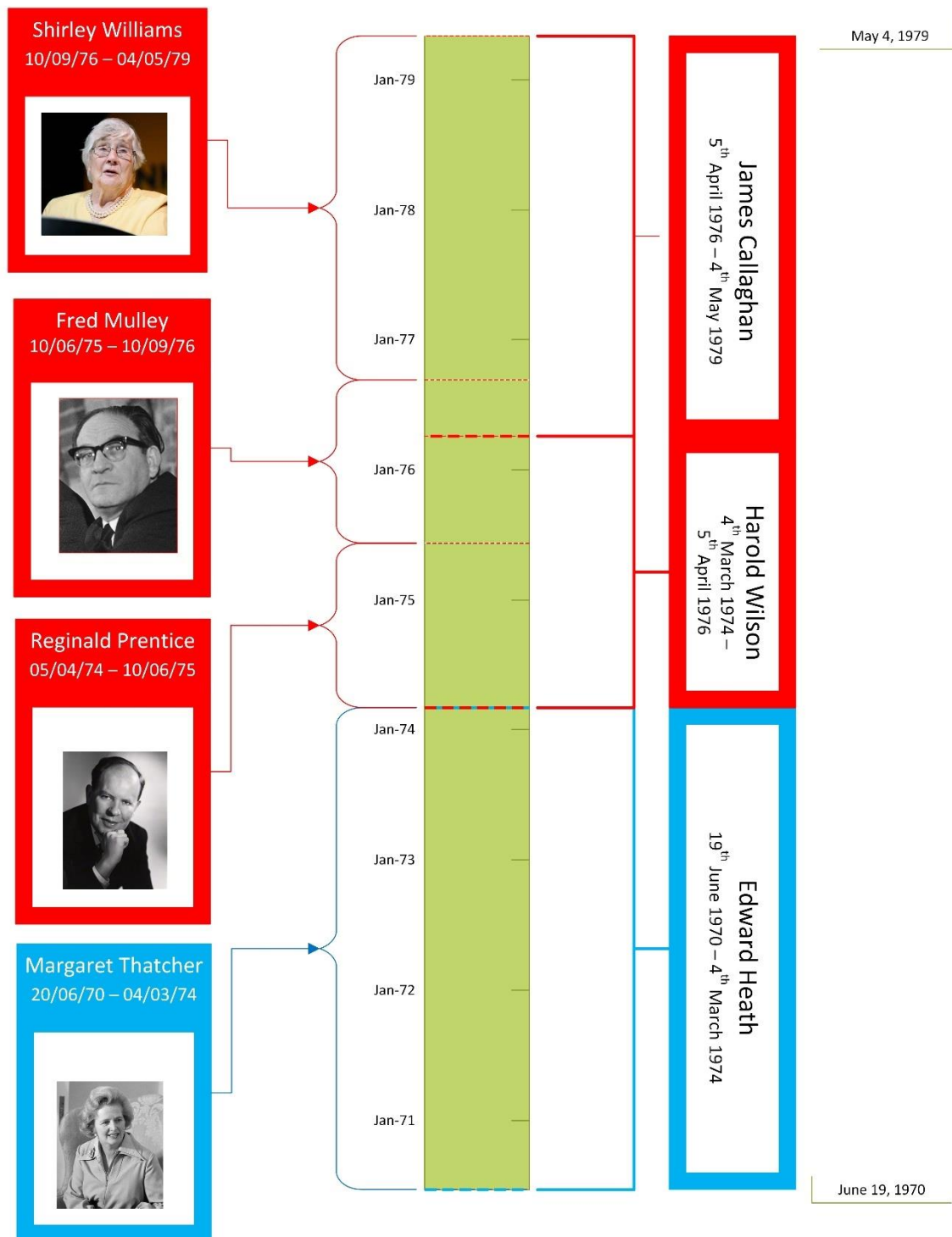
Secretaries of State for Education

Prime Ministers



## Secretaries of State for Education

## Prime Ministers



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